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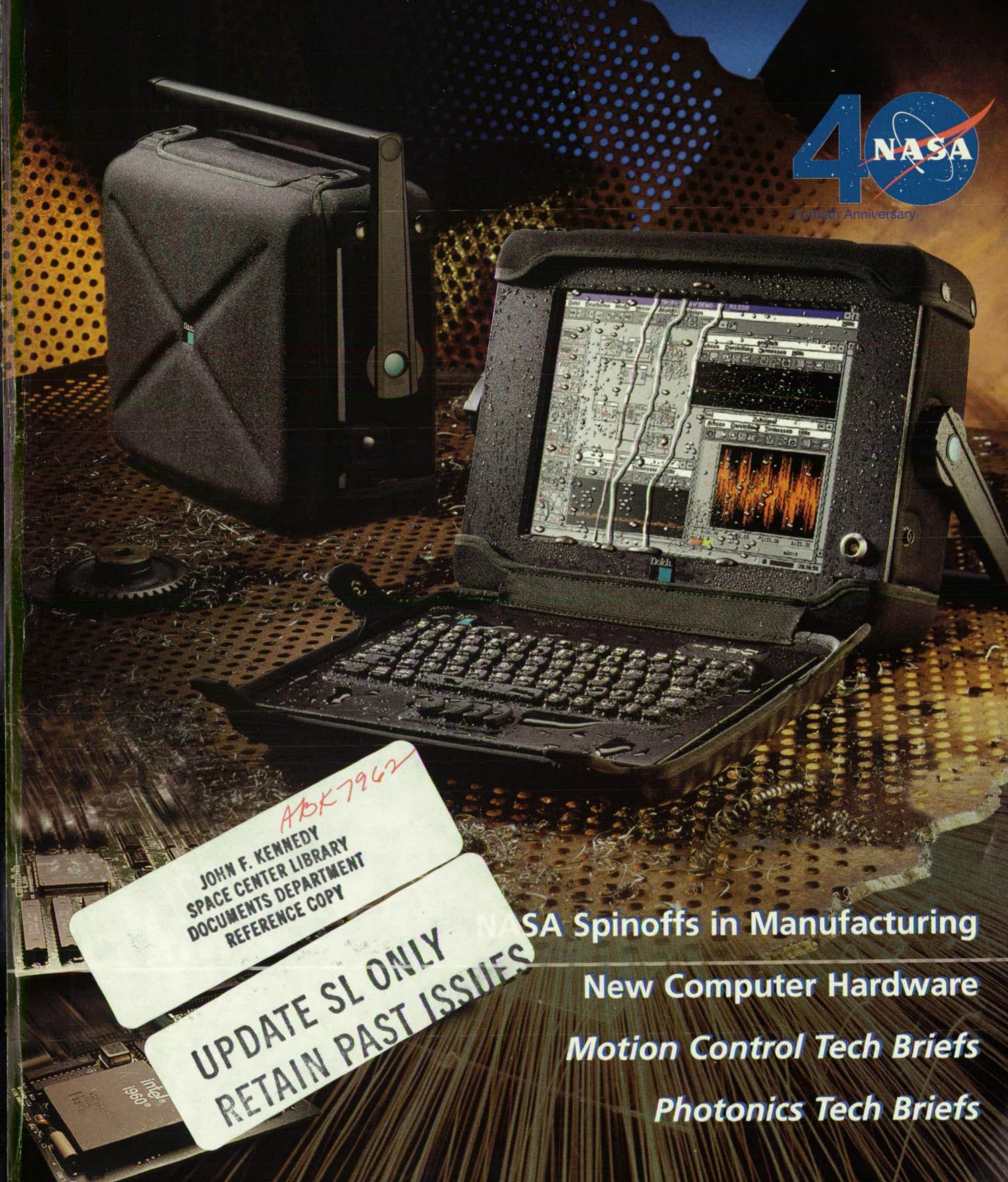
Vol. 22 No. 6

NASA TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING



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New Computer Hardware

Motion Control Tech Briefs

Photonics Tech Briefs

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TECH BRIEFS

June 1998 • Vol. 22 No. 6

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Briefs

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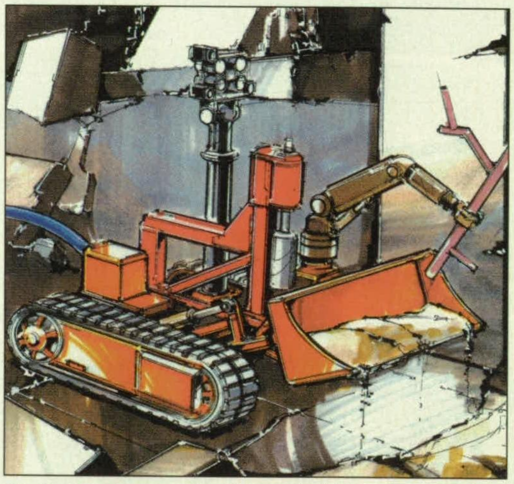
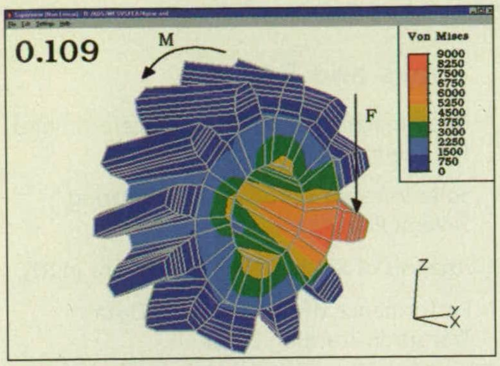


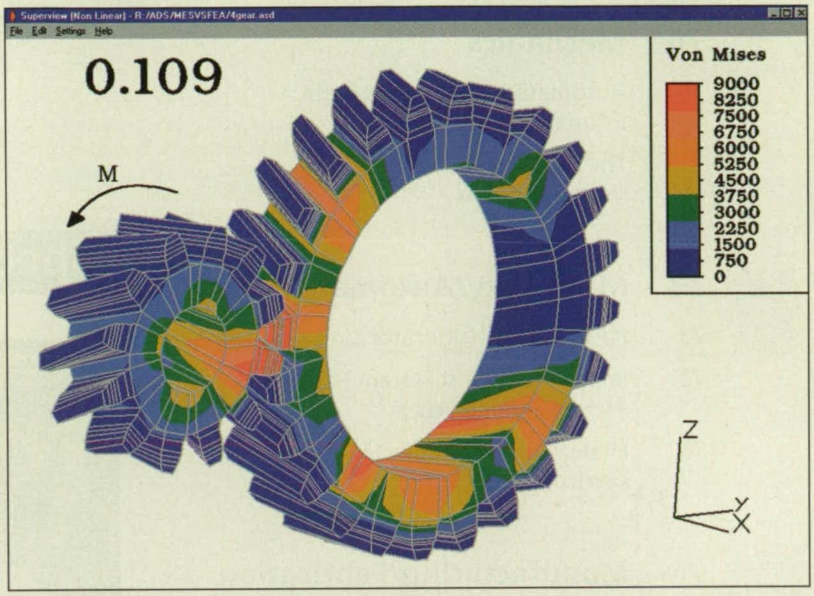
Twelve years ago, the Chernobyl Unit Four nuclear power plant in the Ukraine suffered a massive reactor explosion. In order to contain deadly radiation, a concrete sarcophagus was built around the reactor. That structure, however, is decaying. The Department of Energy (DOE), NASA, and academic and private-sector scientists are collaborating to build a robot called Pioneer, a four-foot-tall, half-ton cross between a tractor and a tank. Pioneer will inspect the interior of the reactor, capturing hundreds of images that will be used to build a "virtual world" of the damaged reactor. Silicon Graphics workstations and supercomputers are being used to create this photo-realistic view. See the Application Brief on page 32 for more information on the Chernobyl project.

(Illustration by Bryon Laffitte)

FEA: Old vs. New



In Linear Static Stress Analysis, the forces must sum to zero. The effect of the second gear is simulated by an assumed force or pressure at a single instant in time.



In Algor's Mechanical Event Simulation, the forces sum to Mass times Acceleration (F=MA). Impact forces are transmitted through actual contact between the teeth during gear acceleration.

Old:

In traditional linear static stress analysis, you begin by building an FEA model. Then you set up boundary conditions to anchor the model in three-dimensional space.

If the boundary conditions fail to stop the model from moving in all six primary directions (three degrees of freedom in translation and three in rotation), the static FEA process cannot work. After setting up the boundary conditions, you then apply the moment (M) or torque, which could be generated by an electric motor, and an assumed force (F) or pressure to simulate the reaction of the second gear. After analysis you will have a stress contour for one point in time.

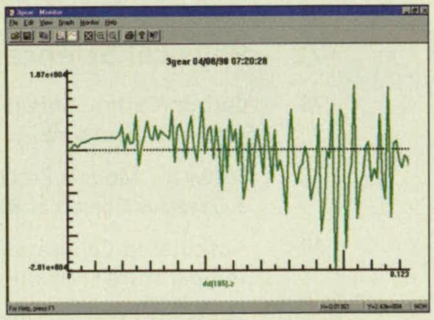
Because the gear teeth are constantly clashing in a random way, the impact forces cannot be known with any precision.

New:

In Algor's Mechanical Event Simulation, you begin the same way by building an FEA model. However, this time you include the second gear.

You place boundary conditions at the pivots. The big gear is free to rotate when forced by the driving gear. Inertia of the entire gear system resists the force of the motor.

When the analysis runs, you will know it's set up properly when you see the gears accelerating and stresses changing as you view the live on-screen "monitor program."



Plot of acceleration vs. time shows high-frequency impacts.

At the end, you see the stresses on all the gear teeth at every point in time.

And, you can make an analysis replay to see the results in real time or slow motion. In addition, you can run a Fast Fourier Transform on the displacement data to highlight any dangers from resonance.

See an analysis replay of this Mechanical Event Simulation at www.algor.com, or contact Algor, Inc. for the latest CD-ROM information/demo pack.

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For More Information Circle No. 507

Contents *continued*

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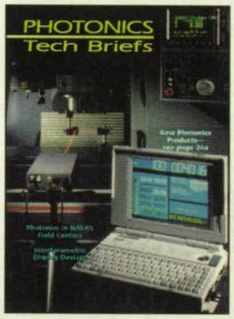

On the cover:

Designed for "lethal zones," the DuraPAC™ fully sealed industrial portable computer from Dolch Computer Systems, Fremont, CA, illustrates one end of the wide spectrum of Computer Hardware and Peripherals highlighted in this month's Special Coverage. Products range from rugged laptops, to desktop workstations, to specialized keyboards, mouses, and monitors. Rounding out our Special Coverage are NASA innovations in areas such as computer networking and system layout. The section begins on page 36.

(Photo courtesy of Dolch Computer Systems)

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NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (206) 683-1005 for the FLC coordinator in your area.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

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Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Bruce Webbon
(650) 604-6646
bwebbon@mail.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Lee Duke
(805) 258-3802
duke@louie.dfrf.nasa.gov

Goddard Space Flight Center
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Jet Propulsion Laboratory
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Langley Research Center
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Lewis Research Center
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Larry Viterna
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cto@lerc.nasa.gov

Marshall Space Flight Center
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Sally Little
(205) 544-4266
sally.little@msfc.nasa.gov

Stennis Space Center
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NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

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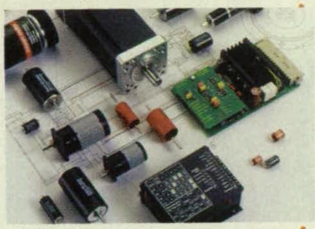
Our patented rhombic wound moving coil motors offer several advantages over conventional DC motors such as much longer brush life and extremely low electrical noise, low mechanical time constant for fast acceleration, low current consumption for extending battery life, no cogging for smooth rotation even at low speeds, and linear speed-torque constants for simple, accurate control.



Typical applications include air samplers, chart recorders, miniature pumps, chopper wheels, laser measuring devices, microscope stages, surgical devices, data storage devices, vision systems, and printers/labelers.

For more information, call or fax Mr. James Talent, Maxon Precision Motors, Inc., Burlingame, CA. Tel: 800-USE-MAXON (800-873-6296), Fax 650-697-2887.

Circle No. 522

16 mm REDUCED COST MOVING COIL MOTOR

Maxon's new A-max 16 mm (0.63 in) diameter motors deliver the performance and lifetime of a moving coil motor, but at a reduced cost due to improved automated manufacturing processes. The patented rhombic moving coil design provides for long life, low electrical noise, fast acceleration and high efficiency. The ironless rotor allows for zero cogging and simple, accurate control. Available with either precious metal brushes or graphite brushes, the power rating ranges from 1.2 to 2 watts. The motor is available either with a single shaft or with a passing shaft. Other standard options include ball bearings/sleeve bearings, and terminals/leads. The motor length is 25.4 mm (1 in) and weighs in at 23g (0.81oz). Several different windings are available to match desired speed with available voltage. Ambient temperature range is from -30° to 85° C (-22° to 185° F), while the maximum efficiency is 77% depending on the winding. The maximum continuous torque from the motor alone is up to 2.53 mNm (0.35 oz-in). Matching gearheads are also available with ratios ranging from 4.38:1 to 4591:1 capable of delivering 300 mNm (42 oz-in) of continuous torque. A matching encoder is also available.

For more information, call or fax Mr. James Talent, Maxon Precision Motors, Inc., Burlingame, CA. Tel: 800-USE-MAXON (800-873-6296), Fax 650-697-2887.

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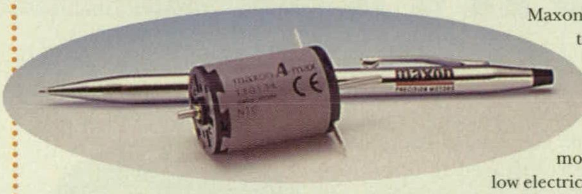
22 mm REDUCED COST MOVING COIL MOTOR



Maxon's new A-max 22 mm (0.87 in) diameter motors deliver the performance and lifetime of a moving coil motor, but at a reduced cost due to improved automated manufacturing processes. The patented rhombic moving coil design provides for long life, low electrical noise, fast acceleration and high efficiency. The ironless rotor allows for zero cogging and simple, accurate control. Available with either precious metal brushes or graphite brushes, the power rating ranges from 3.5 watts to 6 watts. The motor is available either with a single shaft or with a passing shaft. Other standard options include ball bearings/sleeve bearings, and terminals/leads. The motor length is 31.9 mm (1.26 in) and weighs in at 54 g (1.9 oz). Several different windings are available to match desired speed with available voltage. Ambient temperature range is from -30° to 85° C (-22° to 185° F), while the maximum efficiency is 83% depending on the winding. The maximum continuous torque from the motor alone is up to 8 mNm (1.1 oz-in). Matching gearheads are also available with ratios ranging from 4.4:1 to 1620.5:1 capable of delivering 1Nm (141.6 oz-in) of continuous torque. A matching encoder is also available.

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UpFront

Raytek® Corp., Santa Cruz, CA, has introduced the Thermalert® GP two-piece infrared temperature monitoring system that combines a 1/8 DIN monitor with a rugged temperature-sensing head. It provides target temperature readings with 1% accuracy, and displays temperature data on a four-digit LED display. Monitor and sensor functions are configured via the user interface on the front panel. The monitor provides advanced signal processing capabilities such as peak/valley hold, averaging, and adjustable offset. It features a 4-20mA output and two adjustable setpoints/deadbands with alarm outputs that can notify operators of out-of-range conditions. The Thermalert GPR sensor is an 8-14 micron head that combines current loop driven signals for noise-free cable runs with high-resolution 35:1 optics. It features a temperature measurement range of -18 to 538°C.

Product of the Month

For More Information Circle No. 755

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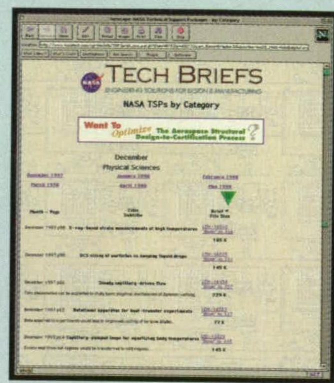
Beginning in July, Technical Support Packages (TSPs) for current-issue and recent (previous six months) tech briefs no longer will be available in printed form through *NASA Tech Briefs* via mail order. They will be accessible on-line through our web site at **www.nasatech.com**.



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Tech Center Marks Successes

Montana State University's new TechLink Center is off and running since its inception a year ago. The center matches NASA technologies with commercial partners in Montana, Idaho, Wyoming, and North and South Dakota, forming partnerships with the electronics, robotics, sensors, software, remote sensing, biotech, and materials industries.

The first company to partner with NASA through the TechLink Center on a remote sensing technology was Positive Systems of Whitefish, MT. The company will work with NASA's Stennis Space Center to develop solutions to problems in the remote sensing, aerial photography, and satellite imaging areas. Positive Systems' new software is expected to solve the problem of joining images acquired at different times. The program integrates a set of correction factors based on NASA algorithms.

Integrated Geoscience of Helena, MT, is working with NASA's Jet Propulsion Lab to evaluate and improve the company's automated feature recognition software, which can recognize and map selected features in remotely sensed imagery. Better remote sensing will enhance decisions over land use, watershed management, development planning, and environmental monitoring.

For more information, visit the TechLink web site at: www.montana.edu/techlink.

NASA Keeps Vehicles on the Right Track

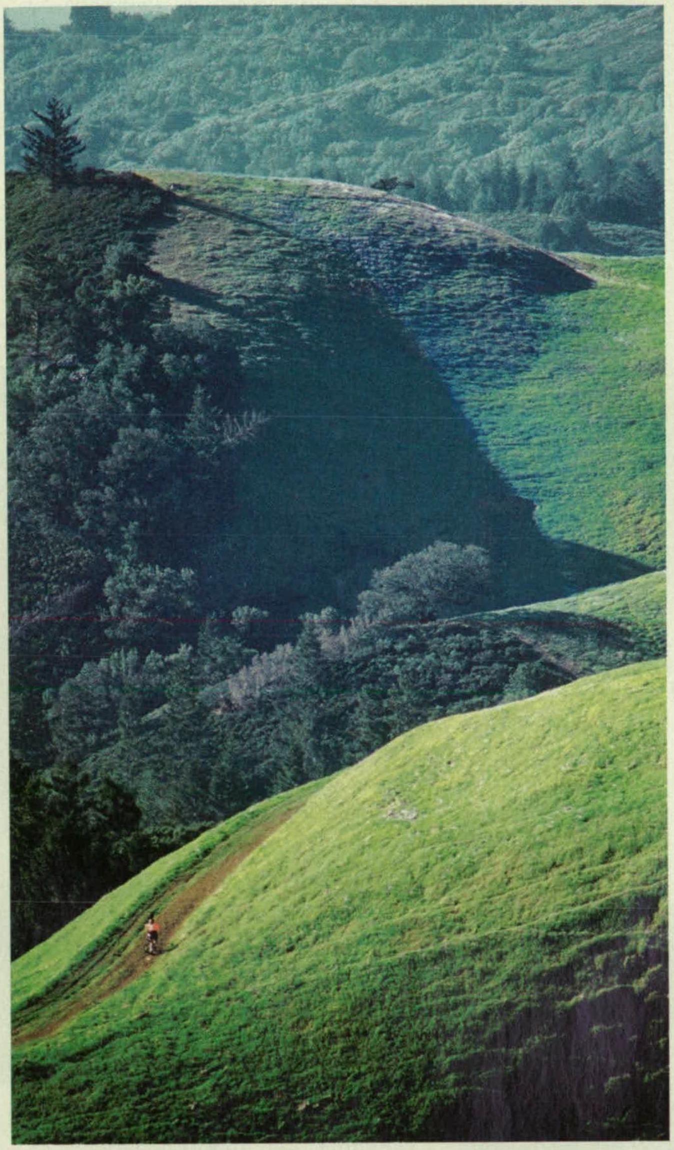
A data management system developed by NASA's Marshall Space Flight Center to handle the flow of information received from experiments aboard the Space Shuttle-based Spacelab was adapted to create an innovative vehicle tracking system for municipalities and private businesses.

The tracking system has its origins in a contract to facilitate accessing specific Advanced X-Ray Astrophysics Facility (AXAF) temperature and vacuum data from a telemetry stream. Scott Johnson of Quality Research in Huntsville, AL, said his company worked with NASA Marshall's Astrionics Lab's Ground Computers Team and Design and Implementation Branch to develop software that would allow engineers to extract specific information from the data stream while testing AXAF in a simulated space environment.

In a commercial spinoff of the software, AVL Systems, also of Huntsville, modified the software to form the heart of a system that can monitor specially equipped vehicles in operation within a specific area, using Windows NT workstations with a map of the area being monitored. The map displays the locations of all tracked vehicles, with color codes indicating their status, such as in service, en route, etc.

For municipalities, it can track police and fire vehicles, ambulances, and public works vehicles, which are equipped with a device that relays a signal to a central dispatch site. The system is activated by logging in the vehicle's starting position via a GPS satellite. As the vehicle moves, the system uses the satellite information to update its location.

For more information, contact AVL Systems at 205-882-1995; Fax: 205-882-0464; e-mail: chasmusi@airnet.net



8830 DIGITAL DOCUMENT SYSTEM

Reader Forum

Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a specific technical problem, or an answer to a question that appeared in a recent issue, send your letter to the address below.

I'm writing in response to an on-line Reader Forum request from Donald Horkheimer regarding a device to move corrosive fluid that would have no moving parts. In the late 1960s, an agricultural engineering student at Colorado State University came up with what might be called a "percolator pump" to transfer insecticides and other fluids — which might be either toxic or corrosive — from a 55-gallon drum.

Basically, it consists of a fairly small (perhaps 3/4" ID) plastic tube which is placed vertically in the barrel with a smaller air hose supplying a simple bubbler at the base of the tube. As the air rises through the tube, it carries with it a surprising amount of fluid. The top of the tube has a U-bend through which the fluid exits into a collector leading to a hose (gravity feed to the implement tank) and the air is vented.

I don't know if such a device will work for Mr. Horkheimer's application. If venting the air to the atmosphere presents a problem, it would not be difficult to design a closed air recirculating system which would have the additional benefit of being able to work at an elevated system pressure.

Stephen Robert Snook
Chief Engineer
Systems Research Services
Port Hueneme, CA

The lightweight, high-performance thermal insulation developed for the space shuttle and described in NASA Tech Briefs *has a direct application as a heat barrier around the hot sections of jet engines. This will translate into fuel savings. Thank you.*

Don Darrow
Boeing Commercial Airplane
Wichita, KS

We own a proprietary inflatable pipe manufacturing machine and process technology. Several formulation improvements have been made as a result of learning of certain chemical characteristics discussed in NASA Tech Briefs*. Thanks.*

C.E. Nelson
Owner
Centerflex International Corp.
Kinnelon, NJ

Post your letters to **Reader Forum** on-line at: **www.nasatech.com** or send to: Editor, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864.
Please include your name, company (if applicable), address, and phone number or e-mail address.

NASA PATENTS

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

Method for Production of Powders

(U.S. Patent No. 5,635,153)

Inventors: Joel M. Stoltzfus and Subhasish Sircar, Johnson Space Center

Metal oxide powders are used in chemical laboratories and in manufacturing processes, but existing methods for producing them involve multistep processes requiring elaborate apparatus that are relatively time-consuming, cumbersome, and expensive. The present invention provides a technique for producing large amounts of oxide powders utilizing combustion with a minimal number of process steps. A material, which may be a metal or metal alloy, is provided in the form of a rod and put in a combustion chamber housing. An igniter is applied to it, and it is then exposed to an oxygen atmosphere, or an atmosphere enriched with oxygen. The igniter causes combustion of the material to produce powdered oxide. In one embodiment of the invention a feeder is provided so that the material can be advanced into the combustion chamber continuously via rollers, moving through a seal so that the chamber's ability to contain the combustion reaction is preserved.

Encyclopedia of Software Components

(U.S. Patent No. 5,632,022)

Inventors: Lloyd V. Warren and Brian C. Beckman, Jet Propulsion Laboratory

The inventors, impressed by the fact that a high proportion of the time spent developing new software systems is used to perform mundane functions that are well known in the art, set out to make it easier to reuse than to reinvent software. The analogy in software to the use of standard parts in hardware is the reuse of previously developed software code, modules, libraries, designs, architectures, documentation, test data, test routines, test strategies, and so on. The inventors assert that the process that a potential consumer of reusable software components must go through consists of these steps: locating, understanding, retrieving, validating, and adapting (LURVA) existing software. In the invention—an encyclopedia of software components—locating is facilitated through a very general classification scheme based on semantic networks, and through tying this scheme closely to a hypermedia browsing-and-searching front end. Understanding is facilitated by describing software with electronically cross-linked text, graphics, animation, audio, video, and typeset mathematics, i.e., hypermedia. Retrieving is facilitated by encapsulating knowledge about network access along with the descriptions of software and by automatically computing closed sets of software items that enable a chosen time to be used as an independent unit or a component.

Security System Responsive to Optical Fiber Having Bragg Grating

(U.S. Patent No. 5,633,975)

Inventors: Charles K. Gary and Meric Ozcan, Ames Research Center

The object of the invention is to provide a key for an optically responsive electronic lock that is convenient to use, not susceptible to being misplaced, with patterns that are not easily duplicated and decode means that are commercially available. The security system consists of a light source, a receptacle, a key, and a decoder. The source provides light along a predetermined path. The receptacle has a passageway with entrance and exit portions located to intercept the light. The key consists of a carrier and a fiber optic, which is located in the carrier to intercept the light at the exit portion of the passageway. This fiber optic has one or more Bragg gratings that reflect the intercepted light into a predetermined spectral pattern. The decoder has means for receiving and decoding the pattern, by comparing it with a preselected pattern and generating an electrical signal when the two match. The signal operates the lock or lights a display of an authentication panel.

For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. See page 14 for a list of office contacts.

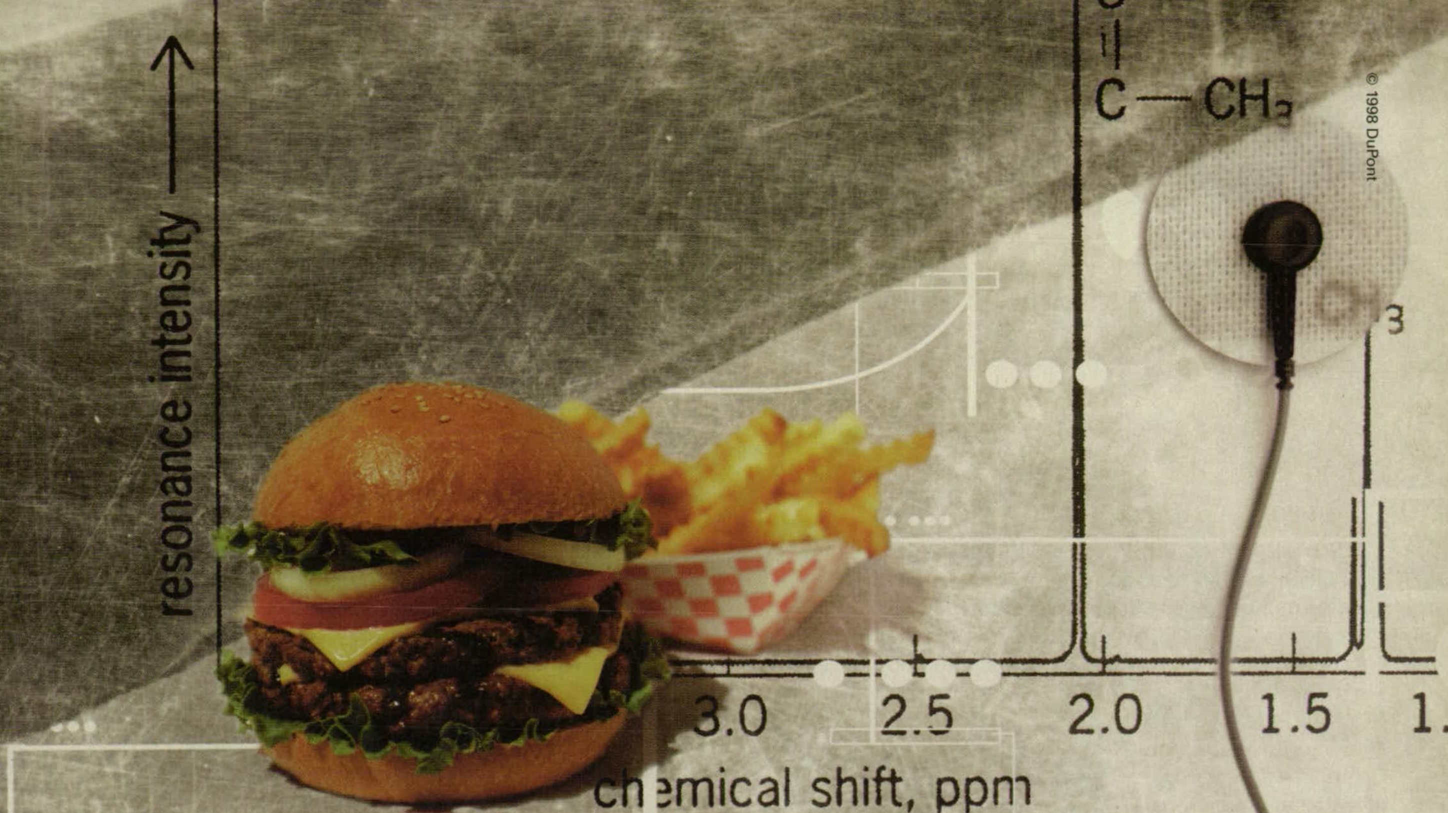

ICEM Surf
The Art of Surface Modeling
ICEM SURF 2.1.0.179 MAGIC+MASTER
Project: dieter
File
List
Objects
Create
Modify
Diagnosis
Display
Windows
Symm
Move
ICEM SURF

After the heart attack, **your doctor recommended** a better diet. Who knew it would include french fries **and chocolate cake?**

Guilt-free fries. Bread enriched with cancer-fighting compounds. Pork that's virtually fat free. A new generation of NMR probes built with DuPont superconducting circuits may soon help scientists create healthier, more nutritious foods.

Since its discovery a decade ago, high temperature superconductivity (HTS) has ranked as one of the greatest and most mysterious scientific discoveries of the 20th century. The ability to conduct electricity without resistance may someday make practical such marvels as trains that float magnetically in thin air, supercomputers that fit inside a shoe box and frictionless flywheels that populate the highways with electric cars.

At last, one of the promises of superconductivity is here—superconducting electronic circuitry. DuPont scientists have pioneered HTS thin film technology for laying down microscopically thin surfaces on wafers and etching circuit patterns into them. What's more, DuPont is now incorporating these HTS materials into devices and subassemblies for use in PCS and cellular communications, radar, MRI instrumentation and high gradient magnetic separators for kaolin clay processing.



As for the potential of these devices, consider nuclear magnetic resonance (NMR) instrumentation. Because superconducting sensors can produce extremely low noise receivers, NMR probes are being developed that are up to 10 times more sensitive than today's equipment. The ability to identify smaller samples with higher accuracy will allow scientists to embark on projects of much greater scope and depth. Conventional NMR has aided DuPont scientists in developing high oil corn, better tasting canola oil and high oleic acid soybeans. Imagine the radically healthier foods that may be created in the future using superconducting probes.

In communications, the advantage of sensitive receivers is equally important. DuPont offers a full foundry service for PCS and cellular components and devices based on HTS thin films such as low phase noise oscillators, ultra-high Q resonators, high-power filters, inductors and high-speed switches. HTS filters have already been successfully demonstrated in the field.

The benefits of such devices include improved call quality, extended cell site range, greater in-building penetration, lower handset transmit power and increased call-handling capacity. In fact, it may be possible to actually skip every other base station in a rural PCS system.

We can't get there alone.
Throughout DuPont history, many of our biggest contributions have come to market through collaboration with other companies. If you are active in the areas of telecommunications equipment, digital electronics, medical instrumentation, scientific instrumentation or satellite components, there may be an opportunity for us to work together and make superconductivity a reality. Fax us with your proposal at 1-302-695-7615. Please limit your correspondence to nonproprietary, public-domain information only.

DUPONT®

Better things for better living

This month, in our year-long celebration of NASA's 40th Anniversary, we take a look at successful spinoff products and new applications of NASA technologies in the area of Manufacturing.

1960s

Echoes of Invention

Echo 1, launched in the early 1960s, was NASA's first experiment in satellite communications. The spacecraft was essentially an enormous balloon, its diameter roughly equivalent to the height of a 10-story building. NASA needed a highly reflective material for Echo's skin so that it could bounce back radio signals. And, because Echo inflated only when it reached orbiting altitude, it had to be lightweight and thin enough to travel inside a beach-ball-sized canister.

An employee inspects vacuum-metallized plastic film.

NASA selected a Mylar polyester coated with a reflective layer of aluminum particles so fine that Echo's skin was half the thickness of the cellophane wrapper on a cigarette pack. This process of metallization — treating materials with a superfine mist of vacuum-vaporized metal to create a foil-like effect — originated in the 19th century. But the technology developed slowly. By the late 1950s, metallized plastics were being produced primarily for decorative purposes, but the demand was small.

NASA's requirements helped build metallization into a flourishing industry, prompting extensive research and development of metallization techniques for applications such as thermal radiation insulation. Metallized film has been used on virtually every U.S. spacecraft since the early 1960s.

The Metallized Products Division of King-Seeley Thermos (KST), Winchester, MA, helped commercialize the NASA-sponsored technology. KST further developed the technology of vacuum-metallizing plastic films, expanding the process to include gold, silver, copper, and zinc. Metallized materials have a variety of commercial applications, including outdoor clothing, food-packaging materials, wall coverings, aircraft covers, and reflective blankets. While the technology existed before NASA's use of it, space use led to greater commercial applicability.

Slicker Than Glass

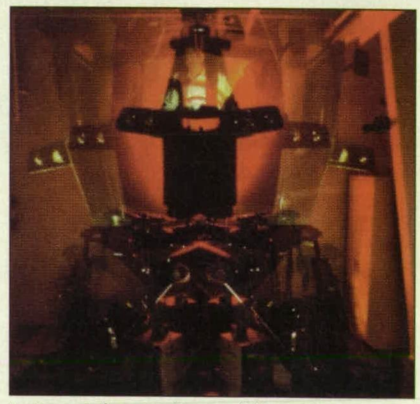
The Orbiting Solar Observatory (OSO), developed by NASA in the early 1960s, was a solar-astronomy spacecraft. NASA's contractor for the satellite — Ball Aerospace Systems Division of Boulder, CO — found that conventional lubricating materials would be unsuitable for long-term exposure to the vacuum of space. To meet NASA's requirements, Ball developed a new family of dry lubricants specifically formulated for long life in space. Researchers also devised processes for applying the lubricants to spacecraft components in microscopically thin coatings.

The dry lubricants worked successfully on seven OSO flights, and Ball scientists began exploring possible non-aerospace applications. The company developed hundreds of variations on the original OSO technology, improving the quality and efficiency of a wide range of commercial products and industrial processes. Applications include solar-energy collection systems, protective coatings for motion-picture film, preservative coating to protect the sound fidelity of phonograph records, lubricants designed to withstand "cold room" conditions in the meat-packing industry, and treating electric motor and generator brushes to reduce brush wear.

1980s

Joining Forces

In 1837, a blacksmith named John Deere perfected the steel plow. The company he founded to manufacture and sell farming equipment has grown into one of the world's largest manufacturing businesses — Deere & Company, based in Moline, IL. Deere now employs 35,500 people worldwide and manufactures hundreds of products, including agricultural tractors, harvesters, industrial and construction equipment, and lawn-and-garden tractors. In the early 1980s, Deere's Technical Center worked with NASA in a multifaceted technical exchange program to explore areas of aerospace research that promised product improvements.



In Deere's human factors lab, engineers study how vibration and noise affect vehicle operators.

The collaboration between NASA and Deere exemplified a different form of the aerospace spinoff process. Deere did not simply reapply technology already developed for aerospace; the company actively participated in the development of new technology through its own extensive R&D capabilities, complementing NASA's efforts.

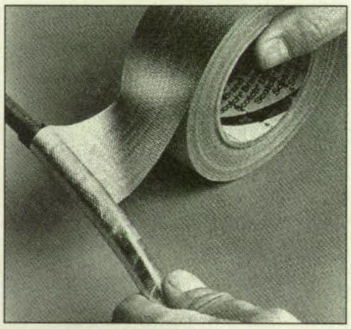
One example of NASA/Deere collaboration involved processing materials under near-zero-gravity conditions. Deere researchers used the low-gravity environment to study what happens to iron as it melts and solidifies in an aircraft-borne furnace. Because cast iron accounts for about 25 percent of the weight of Deere products, any improvement in strength and quality of this

material is vital to product development. Deere's experiments were conducted in a furnace developed by Marshall Space Flight Center and flown aboard a NASA aircraft that achieved near-zero gravity for short periods. Other NASA/Deere projects led to advances in composite materials, ceramics, lubrication, plasma coatings, sensors, and electronics.

Another example of the joint effort is the Stirling engine, an external combustion engine developed with NASA's Lewis Research Center and the Department of Energy as an alternative propulsion system for road vehicles that offers lower fuel consumption and the ability to use a wide variety of fuels. Deere has conducted lab tests of the Stirling engine, in an effort to eventually adopt it as an alternative to the diesel engines currently manufactured.

A Tape for All Seasons

Scotch® Brand Tape 364 is a high-temperature tape originally developed for NASA by 3M's Industrial Tape Division, St. Paul, MN. In aerospace applications, this aluminized glass-cloth tape is used to protect electrical and instrumentation cables and fluid lines from rocket-launch blast conditions — it can withstand prolonged exposure to temperatures as high as 500°F and can function in temperatures as low as -65°F. The tape began commercial production in the mid-1980s, and is now produced by Scotch Brand Tape.



Scotch® Brand Tape 364

No. 364 is a second-generation cable wrapping that combines the best characteristics of aluminum-foil and glass-cloth tapes. Coated with silicone adhesive, it spiral-wraps without cracking and is easily applied to compound surfaces. The tape has high solar-energy reflectance and presents no electrostatic hazard. Non-aerospace uses include the automotive and general transportation industries and heat-reflection applications in high-temperature building construction.

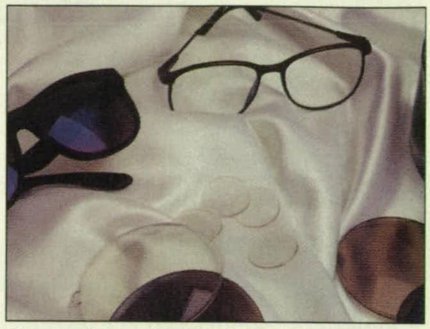
1990s

A Manufacturer's Best Friend

Diamond is the hardest known substance, highly resistant to wear and impervious to most chemicals. It is an excellent thermal conductor and electrical insulator. The mineral is transparent not only to visible light, but also to infrared and ultraviolet. Were it not for their high cost, diamonds would be the ideal material for a wide range of industrial applications. But advances in materials technology offer a lower-cost alternative by coating and chemically bonding an inexpensive substrate with a thin film of diamond-like carbon (DLC).

Diamond films have great potential as chemically inert protective coatings that make machine tools and parts last ten times longer. Other applications include optical instruments, medical equipment, watch crystals, and eyeglasses. Among the American companies involved in DLC commercialization is Diamonex, a spinoff company of Air Products and Chemicals of Allentown, PA, which is using, under exclusive license, NASA technology for depositing DLCs on a substrate.

For more than a decade, NASA's Lewis Research Center has investigated the aerospace potential of synthetic diamond coatings. Lewis developed a method called direct ion-beam deposition for applying DLCs to a substrate. An ion generator creates a stream of ions from a hydrocarbon gas source; the carbon ions impinge directly on the target substrate and "grow" into a thin DLC film. This low-pressure, low-temperature process allows use of plastics and other substrates that cannot withstand the high pressures and temperatures normally used to synthesize diamonds.



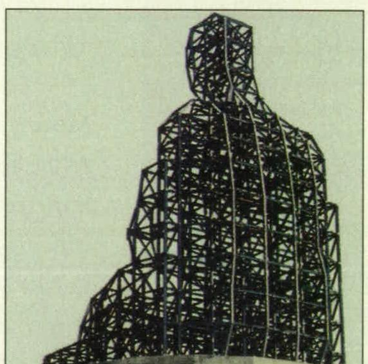
Commercial applications for Diamonex include scratch-resistant eyeglass coatings.

Diamonex has received assistance from Lewis in developing scratch-resistant coatings for plastic prescription eyeglasses. Other commercial DLC applications include coatings for magnetic data-storage discs, surgical needles, and a diamond-coated ball for an artificial hip joint.

Long-Term Protection

The location of NASA's Kennedy Space Center (KSC) on Florida's Atlantic Coast exposes the launch facility's steel structures to a corrosive onslaught of salt spray and fog. NASA required a protective coating that would reduce maintenance cost for the gantries — steel frameworks that provide multi-level access to launch vehicles and other KSC facilities.

Researchers at NASA's Goddard Space Flight Center improved on existing water-based zinc silicate coatings by boosting the ratio of potassium to silicate. The resulting breakthrough in inorganic chemistry provided KSC with an easy-to-use, zinc-rich coating that provided long-term protection with one application. In 1981, NASA granted a license for the coating process to Shane Associates of Wynnewood, PA. The following year, Inorganic Coatings (IC) of Malvern, PA became sole manufacturer and sales agent under the Shane license.



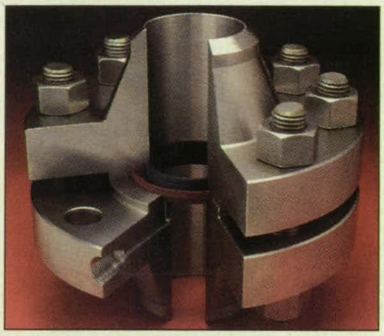
The interior structure of Hong Kong's Po Lin Buddha was coated with IC 531, originally developed by NASA.

IC now markets the product under the name IC 531. Over several years of commercial use, IC 531 has shown exceptional performance in single-coat applications and as a primer in multi-coat systems. This water-based coating is non-toxic, non-flammable, and generates no hazardous wastes. IC estimates that the coating will protect steel structures for "well beyond 25 years." It has been used on a variety of outdoor structures, military vehicles, dock equipment, power stations, bridges, and tractor-trailer frames. In 1984, IC 531 was selected by the National Park Service and the Statue of Liberty Foundation as the best coating for protecting Miss Liberty well into the 21st century. More recently, it was applied to the interior framework of Hong Kong's enormous Po Lin Buddha.

The Connector Connection

In developing its Component Test Facility (CTF), where NASA tests rocket-engine components, Stennis Space Center originally had planned to use conventional clamped connectors on the piping lines that carry rocket propellants and other gases. But Marshall advised against it. Their experience with similar connectors had shown that they were unsuitable for use on lines carrying high-pressure cryogenic fuels. Clamped connectors were prone to leakage when propellant lines were chilled to a pretest temperature of -400°F.

Stennis selected Reflange® of Houston, TX, to develop a new piping connector. They adapted an existing design to include a secondary face seal more tolerant of severe temperature changes. With further testing and refinements, the company produced a connector that met NASA's requirements. Known as the T-Con®, it was used in all CTF locations where severe thermal shock was anticipated.



The E-Con piping connector features a dual-seal flange design.

Reflange developed two spinoff products from this NASA project: a commercial T-Con with a secondary seal for thermal-shock applications in industrial operations; and a second spinoff that emerged in the course of T-Con development. The E-Con® dual-seal flange design offers all the technical advantages of the T-Con, but at a reduced cost in larger sizes in which the quantity requirement is small.

Surviving the Shakes

Along with 400,000 pounds of thrust, each of the Space Shuttle's three main engines generates enough vibration to shake itself to pieces. In developing the engines, NASA required fasteners that could withstand the shock and vibration without loosening. This was a tall order, but NASA wanted even more: The fastener had to have a 15-cycle reuse capability.

Spiralock Corporation of Madison Heights, MI, exceeded NASA's requirements with the Spiralock® internal-thread fastener. NASA tests indicated that this "super fastener" held tight even when subjected to vibration ten times greater than the shuttle requirement. And Spiralock maintained its clamping power after 50 cycles. Every shuttle engine built incorporates more than 750 Spiralock fasteners.

Spiralock's key component is a 30-degree wedge ramp. When clamp load is applied during assembly, the Spiralock thread form locks the standard male fastener in place by drawing the crests of the male thread tightly against the wedge ramp. This wedge-locking makes Spiralock exceptionally resistant to transverse vibration — the major cause of thread loosening — and substantially reduces the risk of fatigue failure.

A High Adventure

Mount Spurr — an active volcano in Alaska — erupted three times in 1992. Because the crater was too dangerous for human exploration, a robot was dispatched to explore its depths. Dante II, developed for NASA by Carnegie Mellon Robotic Institute, was equipped with an array of sensors and imaging devices. The eight-legged robot was able to rappel down the inside wall of Mount Spurr's crater and communicate its findings to scientists, who stayed at a safe distance. An important contribution to this volcano expedition was an innovative strain-gage application from HITEC Corporation of Westford, MA.

HITEC sensors were installed on the four skate runner shoes of the U.S. Bobsled Team's sled.

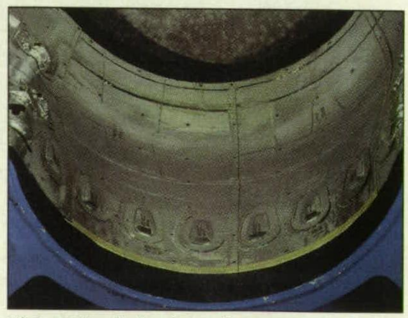
HITEC's assignment was to develop a strain gage-based solution for measuring bending forces on Dante II's legs. The sensor would warn the robot's human operators if a robotic limb got caught in a crevice and if the kickout load on the leg exceeded design limitations. HITEC's engineers had only one month in which to research and design a solution. The resulting sensor system consisted of four strain gages: two measured bending in tension at the surface strain on one side; and two on the opposite side measured compression bending.

The Dante project helped HITEC expand the company's technological capability and led to further developments in strain gage-based sensor applications. HITEC now provides strain-gage services in creating transducers out of such components as Indy racing-car suspension pushrods, NASCAR suspension components, and components used in motion control. HITEC generally supplies sensors to measure strain, stress, and loads on automotive, gas turbine, and structural components. The first U.S.-made bobsled for the U.S. Bobsled Team also has benefited from the company's technology — HITEC installed sensors on the four skate runner shoes to measure vibration forces.

High-Tech Insulation

Protecting the Space Shuttle and its crew during the fiery reentry through Earth's atmosphere requires high-tech protection. Advanced Flexible Reusable Surface Insulation (AFSRI) was developed by NASA's Ames Research Center and integrated into the Shuttle by Rockwell International. In 1974, production of AFRSI was transferred to Hi-Temp Insulation, Camarillo, CA.

For over 20 years, Hi-Temp has provided insulation blankets for the external leeward surfaces of the shuttle. To meet the demands of the shuttle program, the company has created many new technologies. A required combination of low weight and high thermal efficiency prompted examination of new materials and fabrication techniques. Shuttle insulating material must resist temperatures of about 2,000° F for 15 minutes with no burn-through.



Hi-Temp insulation is used on Boeing's 777 — it is assembled on a check fixture and includes a quilted insulation core.

For low-temperature areas of the shuttle, Hi-Temp made molded Fiberglas insulation covered with polyester film. Hydraulic lines and system components are wrapped with this material. The payload bay is protected with Hi-Temp's two-blanket insulation system, and the main engine nozzles use ceramic insulation that withstands up to 2,600° F and extreme vibration.

With NASA's assistance, improvements to Hi-Temp insulation material enable it to withstand heating and cooling cycles; rapid and fluctuating temperature changes; continuous vibration and gravitational stress; and aircraft-engine contaminants. Hi-Temp's shuttle work has led to new production techniques for both aerospace and commercial markets. These include insulation blankets for aircraft-engine exhaust ducts; fire-barrier material to protect aircraft-engine cowlings; molded-Fiberglas blankets for acoustical insulation; and aircraft rescue firefighter suits.

The Smart Bolt

A NASA space solution has yielded a heat-resistant intelligent fastener that may revolutionize manufacturing assembly, especially in the automotive industry. A product of Ultrafast, Malvern, PA, the fastening technology was developed under a Small Business Innovation Research (SBIR) contract managed by NASA's Marshall Space Flight Center. The partnership resulted from a need for critical-fastening appraisal and validation of spacecraft segments coupled together in space. In-orbit assembly requires both lightweight wrenches for enhanced robot-arm mobility as well as remote fastener-load inspection capability.

Ultrafast's intelligent fasteners assure that more precise loads are applied during bolt tightening.

Ultrafast's intelligent bolt utilizes a piezoelectric thin-film deposited directly on one end of the fastener. When electrically excited by an Ultrafast tool, tensile loads can be controlled accurately during the bolt-tightening process. Insufficient bolt preload is usually the root cause of joint failure resulting from joint separation, bolt loosening, or fatigue.

A bolt topped by the low-cost thin-film functions as a transducer for measurement and recording of bolt tensile load. Ultrafast technology uses the relationship between the speed of ultrasonic waves in a material and the stress applied to the material as the basis for computing load measurements. The time of flight of the ultrasonic signal traveling in a fastener increases as the load on the fastener increases. Ultrafast's technology eliminates having to loosen the fastener and disturb the joint during maintenance and inspection.

The Ultrafast system holds distinct advantages for the automotive industry. Components such as powertrains, steering systems, and brakes can achieve higher safety and reliability while minimizing service costs. Use of high-speed impact or impulse wrenches to improve joint integrity and inspection can lower manufacturing costs by reducing joint-assembly time.

Since 1976, *NASA Spinoff* has featured many down-to-earth applications of NASA technology. To learn more about how NASA technologies affect our everyday lives, visit the *Spinoff* web site at: www.sti.nasa.gov/tto/spinoff.html

To Contact Profiled Companies, Call:

Diamonex	215-366-7130
Hi-Temp Insulation	805-484-2774
HITEC Corp.	508-692-4793
Inorganic Coatings	800-345-0531
Reflange	713-682-5105
Spiralock Corp.	248-543-7800
3M	612-733-1110
UE Systems	914-592-1220
Ultrafast	610-889-1348

Next Month:

NASA Technologies Used in Electronics, Sensors & Robotics

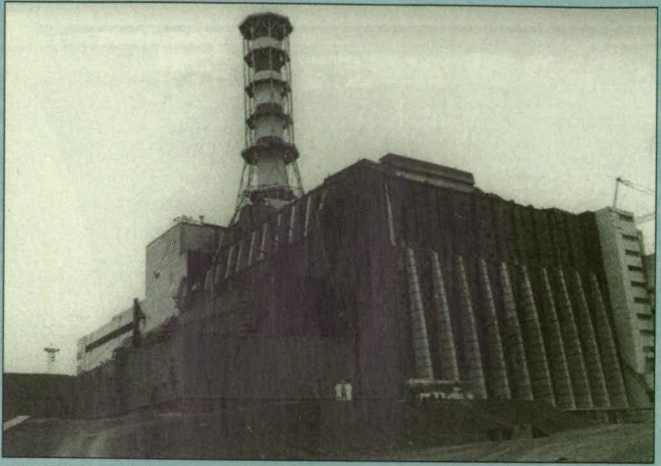
Looking Ahead ...

• UE Systems, Elmsford, NY, recently was awarded an exclusive license from NASA's Kennedy Space Center (KSC) to commercialize a new portable ultrasonic device that can detect leaks at greater distances. The Long Range Ultrasonic Detection Module was developed jointly by KSC engineers and UE Systems after fuel leaks grounded some shuttle launches. NASA and UE Systems incorporated innovative circuitry, improved transducers, collecting horns and contact sensors for increased reliability, sensitivity, and versatility. The new handheld system uses a parabolic collecting horn to double the unit's detection range. The double amplification effect works acoustically to provide a telescopic depiction of leaks. Applications range from leak detection to mechanical and electrical system inspections.

• NASA's Marshall Space Flight Center's Productivity Enhancement Complex (PEC), operated by the Materials and Processes Laboratory at Marshall, works with industry to develop new materials, processes, and assembly techniques. The focal point for cooperative research activities between Marshall and its contractors, the PEC's efforts provide benefits such as reduction of program costs, promotion and exchange of new ideas, and validation of new manufacturing materials and processes. Research cells for welding, rapid prototyping, insulation, robotics, thermal analysis, composites, coatings, cleaning techniques, and other technologies are available. NASA encourages collaboration efforts between NASA and industry to develop advanced manufacturing techniques. Manufacturing process improvements can be designed and tested using the unique capabilities of the PEC. For additional information on the PEC, contact NASA Marshall's Technology Transfer Office or visit the web site at http://techtran.msfc.nasa.gov

Advanced Computers Help Assess Chernobyl Damage

OCTANE™ workstation and Onyx2™ visualization supercomputer
Silicon Graphics
Mountain View, CA
www.sgi.com

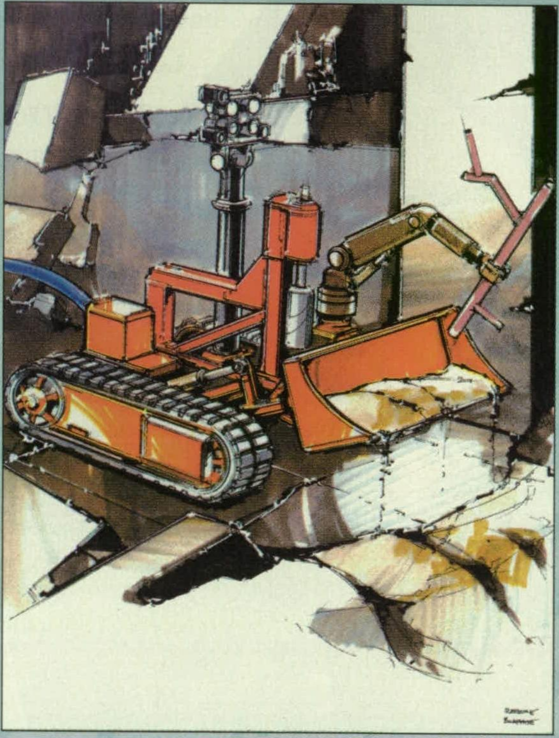


It is feared that the concrete sarcophagus built over the Chernobyl nuclear reactor after the explosion 12 years ago is deteriorating.

According to the U.S. Department of Energy (DOE) experts at Lawrence Livermore National Laboratory, the concrete sarcophagus built over the Chernobyl Unit Four nuclear reactor after the explosion 12 years ago is deteriorating. The DOE, NASA, academic, and private-sector scientists, along with the Ukrainians, are building a high-tech robotics and vision system to analyze and repair the decaying structure. NASA's $2.7 million funding was provided because Pioneer will be testing technology that may be used for future space missions.

Experts at Lawrence Livermore have found that radiation levels inside many reactor rooms at the plant are still so high that people can't work in them without facing serious health risks. Rain is seeping into the facility and draining through radioactive material into ground water. If the sarcophagus collapses or walls inside the reactor area fracture, radioactive dust could be released into the atmosphere and travel hundreds of miles over the Eurasian continent.

The radiation-tolerant, 1000-pound Pioneer robot, being built by Red Zone Robotics of Pittsburgh, PA, runs on tank tracks and is armed with a multi-camera mast, sensors, a bulldozer plow, and a drill strong enough to penetrate concrete. Operators, in a lead-lined room near the reactor core, will drive Pioneer into the contaminated areas to capture images, structural samples, and other measurements.



Pioneer will include a mobility platform and sensor/tooling packages, such as a coreborer, 3D Mapper, manipulator, and environmental sensors that measure temperature, humidity, and radiation levels. *Illustration: Bryon Laffitte*

Silicon Graphics has supplied an OCTANE™ workstation, connected to the robot by a cable, to build virtual reality maps of the rooms. It will help the operator know the exact position of the robot within the radioactive area; convert the images from the camera head into a computerized surface mesh; color the mesh with the camera images; display the final mesh within the context of the rest of the building; and analyze core samples for structural stability. The workstation will be disposed of after the mission because of its exposure to radiation. A second OCTANE workstation will be housed in Chernobyl's administrative building, and a third, residing at the University of Iowa, will be connected to the other workstations via a NASA satellite link.

NASA Pioneer team members are creating a more advanced version of the virtual reality software developed by NASA Ames Research Center for the Mars Pathfinder mission. Using futuristic software recently developed at the University of Iowa, Pioneer operators will "see" what the robot sees on their workstation's video window. Next to this window, other windows will show different views of the robot as it moves through the virtual world it creates when it enters a room.

"Our work with the National Robotic Engineering Consortium is helping to usher in a new era where robots and high-performance computers do work too dangerous for humans," said Dave Lavery, Telerobotics Program Executive at NASA Headquarters. "This is an example of how NASA's technology can be used to benefit private industry."

Using the Onyx2 visualization supercomputer at the University of Iowa, Pioneer team members will fly through the photo-realistic world of Chernobyl created by the OCTANE workstations to assess the structural integrity of the reactor. They will be able to inspect the damage done by the explosion, and determine how much fuel-containing material melted into floors and flowed into lower levels of the building. Other information collected by Pioneer, such as temperature, humidity, and radiation levels, will be integrated into the 3D computerized model.

In a test of the camera system and associated software performed this spring, the robotics team acquired a panoramic 3D map of a construction site at the University of Iowa, and drove a virtual Pioneer robot through it using Silicon Graphics equipment. Pioneer is scheduled to begin mapping the Chernobyl reactor in November; output of the project should be available to the public by December.

For More Information Circle No. 756

Commercialization Opportunities

Hardware-Command-Decoding ASIC

This integrated circuit, designed to decode digital command signals transmitted from ground to a spacecraft, performs functions that previously required several different circuits. It takes less space and consumes less power. A terrestrial version of this circuit could possibly be used to decode digital commands for a mobile robot.
(See page 42.)

Column-Loading Input Chip for Neural-Network Module

A conceptual integrated circuit would serve as an interface between various sources of image data and a three-dimensional analog neural network. All functions would be performed within a cycle time of 250 ns.
(See page 46.)

Lightweight, Radiation-Resistant EMI Shields

Graphite-fiber polymer composites intercalated with select molecules or atoms can serve as effective EMI shields and at a fraction of the weight of aluminum boxes.
(See page 54.)

Instrument Records Electric Fields Generated by Lightning

A portable self-contained compact instrument measures and records transient electric fields generated by nearby lightning strikes. This instrument and a companion instrument measuring magnetic fields can be used to detect damage or disruption of sensitive electronic equipment in thunderstorms.
(See page 56.)

Optoelectronic System Measures Tile Cavities

A hand-held system produces a three-dimensional measurement of a tile cavity in less than one second. An earlier procedure took more than 30 hours.
(See page 58.)

Reducing CTE Mismatch Between Coatings and Si-Based Ceramics

Two techniques are proposed to reduce thermal-expansion mismatches between substrates made of silicon or silicon-based materials and surface coats that protect these substrates from chemical attack in oxidizing and/or corrosive environments.
(See page 66.)

Single Crystal Nickel-Base Superalloy

This is a modified composition designed for use as a turbine blade and vane alloy for the space shuttle main engine. The superalloy exhibits significantly better fatigue and crack-growth resistance than previous alloys, particularly under severe hydrogen-embrittling conditions.
(See page 68.)

Automated System for Acting on Findings From Inspections

Real-time access by all concerned parties fosters understanding of the condition of hardware.

Stennis Space Center, Mississippi

The Automated Nonconformance System, based at Stennis Space Center, is a computer network dedicated to administration of inspections and repairs of rocket engines. This automated system was developed to replace a manual system in which paper documents were used to document the steps of inspection and repair processes, and in which the documents had to be handled and transferred repeatedly according to complex procedures designed to ensure the completion of interdependent process steps in the correct sequences.

The basic paper document in the manual system — called the "Inspection Discrepancy and Correction Record" (IDCR) — has been converted into a collection of menu-driven interactive alphanumerical and graphical computer displays (see figure) in the automated system. It is still necessary to follow the complex procedures, but the automated system eliminates the paperwork delays and the potential for paperwork error, and enables all interested parties at diverse locations to gain access to inspection and repair data in real time. In so doing, the automated system fosters a high degree of awareness of the condition of the inspected and repaired hardware and helps to ensure that all technical and organizational requirements are satisfied.

The automated system affords capabilities to generate IDCRs, to import photographs and drawings from previous inspection and repair processes, to apply and void the electronic equivalent of stamps that were previously applied to paper to document authority to perform or authorize various process steps, to identify required process steps that have not yet been completed, and to perform numerous other functions essential to documenting inspection and repair processes. Passwords are used to control access to the system, and as evidence of authority to apply and void stamps. The automated system also performs audits to prevent both (1) duplication of work and (2) shipping out a piece of hardware before all required process steps have been performed, all necessary stamps applied, and all documentation completed.

This **Interactive Display** is one in a sequence of such displays presented to the user for entry of data into an IDCR.

This work was done by Victor O. Alfaro, Sr., and Robert M. Robb of Boeing, Rocketdyne Propulsion & Power for **Stennis Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category,* ***or circle no. 121*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). SSC-00054*

Computer System for Managing Construction Projects

Stennis Space Center, Mississippi

An automated system of computer hardware and software has been developed for managing construction projects at Stennis Space Center. This system replaces an older collection of paper-based subsystems, wherein documents were copied, filed, and distributed in labor-intensive processes. Data collected in the older system were not readily accessible, cross-referencing of information in conjunction with changes was difficult, and there was no way of evaluating effects of changes on schedules. The present system includes a commercially available server and workstations running software constructed largely from commercially available office, data-base, graphical, and spreadsheet software. The system features several data bases with a user-friendly interface, which provides on-line help, plus "intelligent" forms for electronic reporting in standard formats. Drawings and specifications can be retrieved, and "red-line" comments can be added. Change packages can be reviewed on-line from remote locations. The system provides security through control of access according to the user's authority to initiate, review, or determine the statuses of change packages and schedules.

This work was done by Catherine L. Farve of Lockheed Martin for **Stennis Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category,* ***or circle no. 122*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). SSC-00061*

Computer Network for Management of Inspection Data

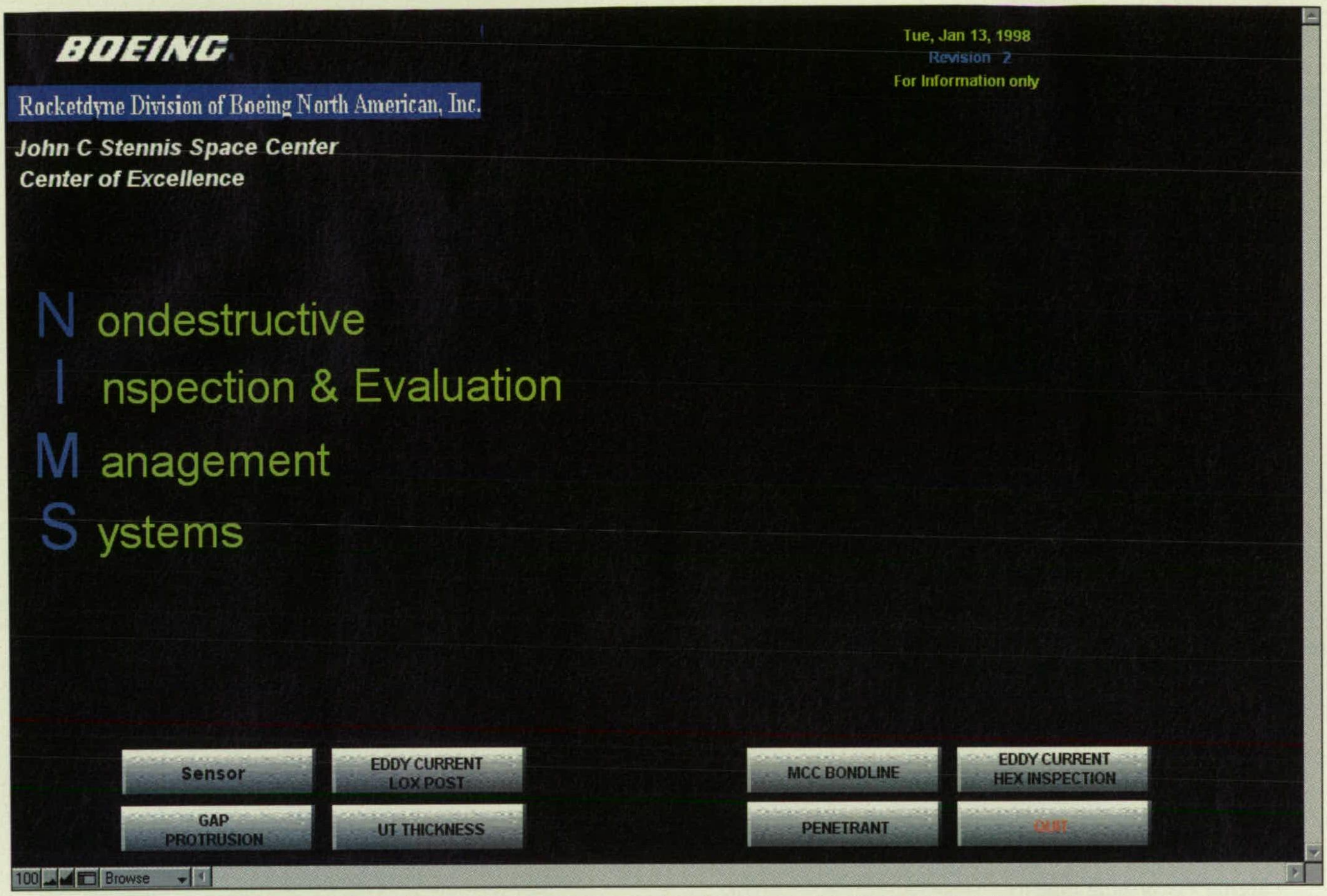
Users need not travel to view original inspection records and archival documents.

Stennis Space Center, Mississippi

The *N*ondestructive *I*nspection and Evaluation *M*anagement *S*ystem (NIMS), based at Stennis Space Center, is a computer network dedicated to administration of a large data base pertaining to nondestructive inspections of rocket-engine components. The NIMS serves as both an electronic archive of inspection records and as a communication medium. Inspection records can be in a variety of forms, include ordinary photographs, fluorescent-penetrant images of cracks, eddy-current traces, images from ultrasonic scans, and sketches.

One important benefit afforded by the NIMS is providing rapid, easy access to records of previous inspections. Inspectors and engineers often need to view such records to obtain guidance in the interpretation of records of new inspections and in the development of new inspection techniques. Before the development of the NIMS, it was necessary to engage in a labor-intensive and time-consuming procedure of retrieving original inspection records from archives, photocopying them, and sending the photocopies to the requesting engineers and inspectors.

Another important benefit afforded by NIMS is enabling a person at one location to view, in real time, the record of an inspection performed by another person



Computer Displays With Full Graphical Capabilities enable individuals at various locations to view inspection records.

at a different location, in order to discuss or confirm the interpretation of the record. Before the development of the NIMS, it was common practice to transmit copies of the inspection records by facsimile ("fax") for this purpose, but the degradation of image quality by facsimile transmission often rendered the copies useless, making it necessary for the assisting engineer and inspectors to travel to the inspection sites. With the NIMS, one can view a photographic-quality copy of an inspection record from any location in the network.

The NIMS is compatible with IBM and Macintosh, or compatible, computers. It accommodates new inspection records and new types of inspections as needed, without extensive programming changes. Security is maintained by requiring passwords for access by users and guests.

This work was done by Victor O. Alfaro, Sr., Robert M. Robb, and Michael F. Reynolds of Boeing, Rocketdyne Propulsion & Power for **Stennis Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category,* ***or circle no. 113*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
SSC-00055

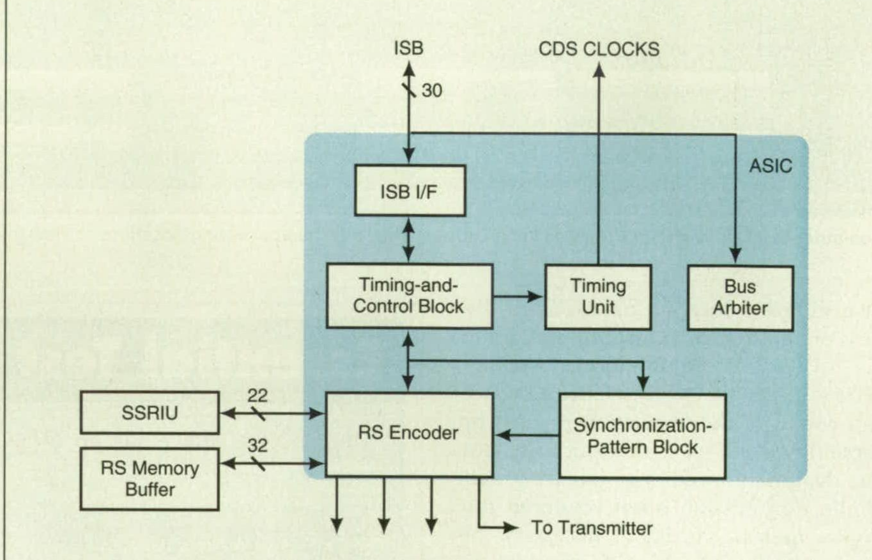
ASIC for Reed-Solomon Coding and Related Functions

Implemented in the ASIC is a portion of the spacecraft uplink protocol specified in the widely used Consultive Committee for Space Data Systems (CCSDS) international standard.

NASA's Jet Propulsion Laboratory, Pasadena, California

The Reed-Solomon downlink application-specific integrated circuit (RSDL ASIC) performs Reed-Solomon encoding of telemetry data, internally generates all timing and control signals necessary for the RS encoder, transfers frames of encoded data to a radio transmitter, and performs ancillary timing and control functions. The RSDL ASIC was designed for incorporation into a spacecraft downlink telemetry system, wherein the multiple functions involved in downlinking of telemetry transfer frames previously required interfaces with many discrete circuits and components. The RSDL ASIC may also be adaptable to terrestrial applications (e.g., recording in the entertainment industry) that involve Reed-Solomon encoding.

The RSDL ASIC (see figure) contains six distinct functional hardware/software blocks; an intersubassembly bus interface (ISB I/F), a timing-and-control block, a timing unit (not to be confused with the timing-and-control block), a bus arbiter, a Reed-Solomon (RS) encoder, and a synchronization-pattern block. All of these functional blocks are integrated in a highly efficient manner to fit on one chip. This ASIC operates in conjunction with a solid-state recorder interface unit (SSRIU), a static random-access memory (SRAM) that serves as an RS memory buffer, and a flight computer to forward telemetry transfer frames to the radio transmitter.



The **RSDL ASIC Contains Six Hardware/Software Blocks** that perform functions that previously required interfaces to many external circuits.

The timing-and-control block generates timing and control signals for the rest of the RSDL ASIC (including the timing unit) and keeps track of operational modes. Commands are carried out in the timing-and-control block, which then generates control signals for the synchronization-pattern block and the RS encoder to either shift the synchronization pattern, encode the message, or shift out the RS check bytes. The timing-and-control block also causes the timing unit to set or reset the spacecraft time and to generate the downlink rate used in the RS encoder. It swaps buffers and provides logic to force transfer frames to synchronize with a real-time-interrupt and use a specified downlink buffer thereafter. It captures the time when the first frame of the downlink buffer is sent out. It provides internal status and interrupt signals for software.

The synchronization-pattern block contains hard-wired logic circuitry that

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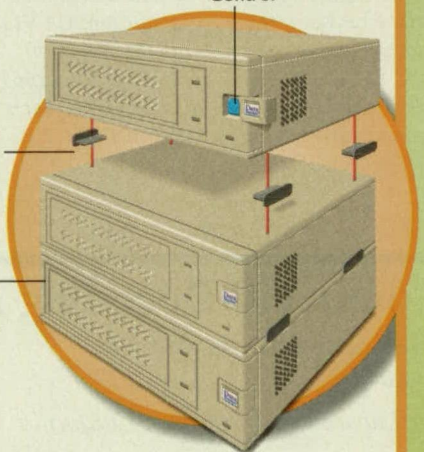

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For More Information Circle No. 501

implements a standard synchronization pattern. It shifts data out serially to the RS encoder for every downlink frame, starting with the most significant bit.

The RS encoder block is based on the Berlekamp architecture and implements a standard (255, 233) RS code with an interleave depth of 5. In addition to the RS encoder, the RS encoder block includes a multiplexer to select input from either the synchronization-pattern block or the SSRIU. The RS encoder block is connected directly to the RS memory buffer.

The timing unit generates clock frequencies used throughout a command-and-data subsystem of the spacecraft. The timing unit includes a timing-chain section that converts the main clock signal into clock signals at most of the frequencies needed for that subsystem. From an oscillator with a frequency of 11,944,800 Hz, the timing chain generates a 64.005-Hz signal for the engineering flight computer, a 2,048.148 Hz signal used by a hardware command decoder, a pseudo-16385.185-Hz signal used within the timing unit, and a 32-Hz spacecraft clock signal. The pseudo-16385.185-Hz signal is used in conjunction with counters to generate the 32-Hz signal with high resolution in the following way: A 37-bit counter toggles the upper 32 bits of spacecraft time, giving resolution of 1/32 s. Another counter of 9 bits toggles a 14-bit subsecond time word.

The bus arbiter is the only unrelated block inside the RSDL ASIC. It contains circuitry to arbitrate the ISB between four possible bus masters.

The ISB I/F contains the logic circuitry that serves as an interface between the RSDL ASIC and an external bus arbiter or an engineering flight computer via the ISB. Software that resides in an external computer reads from and writes to internal registers in the ASIC via the ISB I/F. This block indicates whether data are stable and whether data written by the ASIC are captured correctly.

Notable features of the RSDL ASIC (in addition to those mentioned above) include the following:

- It provides a spacecraft clock to keep track of time from 0 to 136 years in 61.03-ms intervals;
- There is a correlation between spacecraft time and the first bit of a defined transfer frame;
- It is easy to reconfigure the RSDL ASIC to other applications: The length of the transfer frame is programmable, software defines the time of the resynchronization of the transfer frames, and the RS encoder can be turned on and off; and
- Software that resides in the flight computer can read and write status and interrupt signals generated by the RSDL ASIC.

This work was done by James A. Donaldson, Huy H. Luong, and Steven H. Wood of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category,* ***or circle no. 180*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Refer to NPO-19614, volume and number of this NASA Tech Briefs *issue, and the page number.*

Hardware-Command-Decoding ASIC

Advantages include compactness and low power consumption.

NASA's Jet Propulsion Laboratory, Pasadena, California

A hardware-command-decoding application-specific integrated circuit (HCD ASIC) is designed to decode digital command signals transmitted from a ground station to a spacecraft (uplink commands). Implemented in the ASIC is a portion of the spacecraft uplink protocol specified in the widely used Consultative Committee for Space Data Systems (CCSDS) international standard. A terrestrial version might be useful, for example, in decoding digital command signals for a mobile robot. The HCD ASIC performs functions that previously required several different circuits, while taking up less room and consuming less power. Implemented on a single silicon-based chip in a 256-pin

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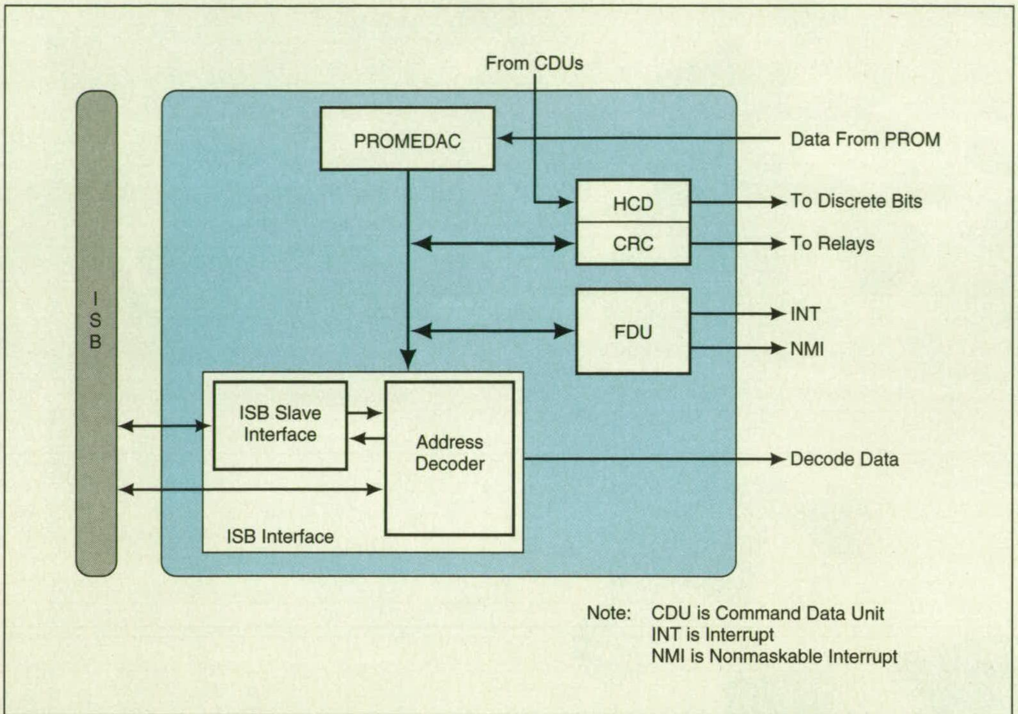

The **HCD ASIC** performs functions that previously required several different circuits, while taking up less room and consuming less power.

package, this ASIC resists both permanent damage and single-event upsets (bit-flips) produced by ionizing radiation. Tested ASICs are available to users.

This ASIC is designed to operate in conjunction with (1) an engineering flight computer (EFC) connected via an intersubassembly bus (ISB), (2) critical relay controllers (CRCs), and (3) a start-up programmable read-only memory (PROM). The figure shows the hardware and software functional blocks of the HCD ASIC. In addition to the HCD block, this ASIC contains a block that performs error detection and correction (EDAC) on data that comes from the PROM, a CRC block, an ISB interface block, and a fault-detection unit (FDU). The blocks are integrated in a highly efficient manner to make them fit together on the single chip. A key feature of this ASIC is the ability to accelerate processing in the detection of "start" data sequences and in EDAC, using parallel processing. Another key feature of this chip is the use of the double-buffer method for read/write/status and for resolving overruns of data.

The data from the PROM are in the form of 16-bit words with 6 parity bits. The PROMEDAC corrects any single-bit error and signals to the ISB bus mas-

ter that it has done so. When the PROMEDAC finds an uncorrectable error, it gives notice to that effect by sending out a "bad" parity signal on the data-bus portion of the ISB.

The FDU includes a watchdog timer and provides interrupt-control support, reset control, and eight discrete outputs that facilitate the exchange of information on the integrity and operational condition of the system.

The ASIC receives a serial, digital data stream as well as a clock signal and a "lock" signal from the uplink data receiver. Two parallel-processing algorithms are used in the HCD block, where traditionally a serial process has been used. "Start" detection is performed by checking the 32 most recent bits of data with the acquisition sequence followed by the "start" sequence. EDAC is also performed by using Perlman's (1980) serial algorithm in a parallel process. A search of uplink data is performed, depending on the "active" or "inactive" state of the HCD. Whenever the "lock" signal is not present, the ASIC goes into the "inactive" state and ignores the uplink. When the "lock" signal appears, the ASIC goes into the "search" state and starts searching uplink data for the "start" sequence. It then goes into the "decode" state and starts decoding code blocks.

EDAC is performed on each code block, and the code block is placed in a data buffer accessible via software. A "tail" sequence forces the ASIC back into the "search" state. Software must fetch a code block from the data buffers (described below) and perform the format checks and interpretation of data. The ASIC presents code blocks to software that pieces them together to form larger frames.

The ASIC contains two data buffers that are used to pass each uplink code block to the software. Each buffer consists of four 16-bit registers and can hold one 64-bit code block. These two data buffers enable the software to read one buffer while the hardware loads the other buffer.

The CRC block communicates directly with the HCD block. It contains data on the state of the command-and-data subsystem of the spacecraft and on the configurations of other parts of the spacecraft. The CRC block includes CRC and EFC mask registers, into which data are written from the ground by use of a specific transfer-frame format. The CRC block includes an EFC/CRC interface that comprises three registers that store 24 volatile CRC bits. These bits are readable and writable through the ISB. An HCD/CRC interface also provides 24 nonvolatile control of relays. Relay state may be changed ahead through the ISB.

The ISB interface connects the ASIC to the outside world through the ISB bus. It also serves as the main interface between the EFC and the command-and-data subsystem. It generates all necessary ISB bus timing signals.

This work was done by Gary S. Bolotin, James A. Donaldson, Huy H. Luong, and Steven H. Wood of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category,* ***or circle no. 152*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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For More Information Circle No. 419

ASIC Physical Layout for the HCD ASIC

HCD ASIC performs a number of functions at unprecedented speed.

NASA's Jet Propulsion Laboratory, Pasadena, California

An integrated circuit (IC) physical layout has been developed for the HCD ASIC — an application-specific integrated circuit that decodes digital command signals transmitted from a ground station to a spacecraft (uplink commands). The HCD ASIC is described in "Hardware-Command-Decoding ASIC" (NPO-19615), which appears elsewhere in this issue of *NASA Tech Briefs*. The present physical layout will be converted to a mask for IC fabrication of the HCD ASIC.

The physical layout has been extensively simulated for its functions of receiving and decoding the uplink commands through a programmable read-only memory (PROM) interface, including conversion of the command data from the serial uplink format to parallel format. At the same time, the HCD ASIC provides detection of some triple bit errors, detection of all double bit errors, and correction of all single-bit errors in the uplink commands, plus detection of hardware faults, all at unprecedented speed. Another unique feature is the use of the double-buffer method for read/write and status for resolving overruns.

This work was done by Gary S. Bolotin, James A. Donaldson, Huy H. Luong, and Steven H. Wood of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category,* ***or circle no. 127*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Refer to NPO-19628 , volume and number of this NASA Tech Briefs *issue, and the page number.*

Column-Loading Input Chip for Neural-Network Module

All functions would be performed within a cycle time of 250 ns.

NASA's Jet Propulsion Laboratory, Pasadena, California

The column-loading input chip (CLIC) is a conceptual integrated-circuit chip that would serve as an interface between (1) any of various sources of image data and (2) a three-dimensional analog neural network (3DANN) of the type described in "Neural-Network Modules for High-Speed Image Processing" (NPO-19881), *NASA Tech Briefs*, Vol. 21, No. 10 (October 1997), page 26. The overall functions of the CLIC (see Figure 1) would be to load 8-bit digital image-intensity signals from a 64 × 64 array of pixels, convert these digital signals to an array of 64 × 64 analog voltages, and couple these voltages simultaneously to all of the corresponding 64 × 64 input terminals of the 3DANN. To prevent a data-input bottleneck, the CLIC is designed to perform these functions within a 3DANN-cycle time of 250 ns. The digital-to-analog conversion

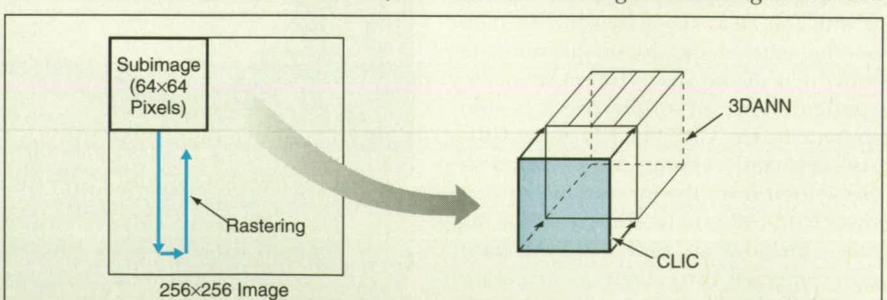

Figure 1. The **CLIC Would Serve as an Input Interface**, for example, to perform rastering on a sequence of digitized 64 × 64-pixel subimages from 256 × 256-pixel image source and digital-to-analog conversion for input to a 64 × 64-pixel 3DANN.

would be accomplished in only about 140 ns, leaving about 110 ns for processing by the 3DANN. The CLIC is also designed to satisfy requirements of compactness and low power consumption.

As part of the design to achieve the required high speed, the digital-to-analog-conversion would be performed locally for each of the 64 × 64 inputs to the 3DANN, by use of a 64 × 64 array of multiplying digital-to-analog converters (MDACs) at the corresponding locations. The input digital image-intensity signals for the MDACs would be coupled to the MDACs in pipeline fashion, by use of row and column arrays of 8-byte shift registers (see Figure 2).

The data would be shifted into the CLIC in parallel 8 bytes corresponding to rows or columns of pixels in the source image. It would be necessary to accommodate input in row or column groups of pixels in order to enable changes in direction of rastering when a 64 × 64 array of pixels reached the edge of a larger image of which it was a part.

For input in columns, the data would be shifted in rightward from the left edge; for input in rows, the data would be shifted in downward from the top edge or upward from the bottom edge. As the data for each successive column or row of new data was shifted in, the data already in each of the shift registers in the interior of the array would be shifted rightward (for input by columns) or up or down (for input by rows), and the data in the registers in the rightmost column (in the case of column input) or in the bottom or top row (in the case of row input) would be destroyed and replaced by new data.

While the data were being shifted into the CLIC, the MDACs would continue to operate on the data from the preceding 3DANN cycle. When all the data for a 64 × 64 array of pixels had been shifted in, all MDACs would simultaneously perform analog-to-digital conversions on the current contents of their local shift registers. After a settling time of about 140 ns, the analog output voltages of the MDACs would be ready for processing by the 3DANN. During the remaining 110 ns of the cycle, these voltages would continue to be available to the 3DANN for processing, and image data for the next cycle would be shifted in.

This work was done by Tuan A. Duong of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components & Circuits category,* ***or circle no. 189*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Refer to NPO-20033, volume and number of this NASA Tech Briefs *issue, and the page number.*

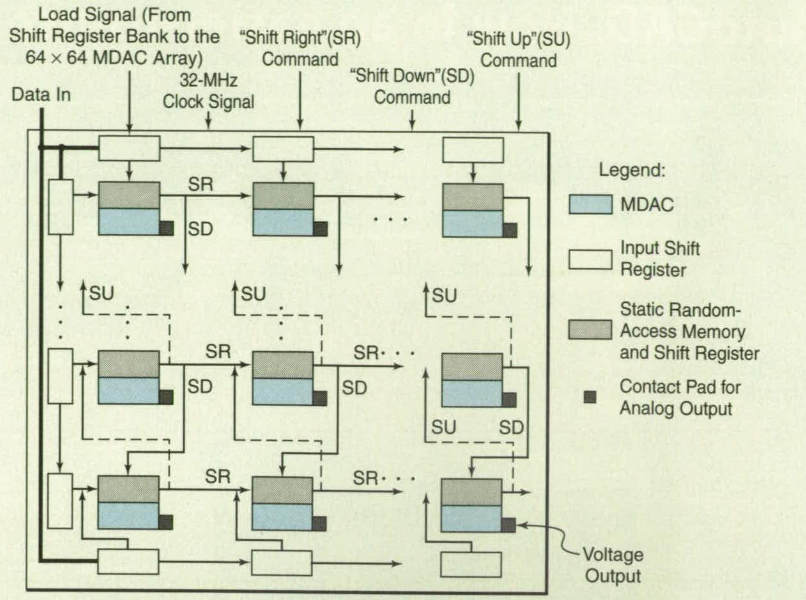


Figure 2. The **CLIC Would Contain an Array of MDACs** and shift registers. Digital signals at a basic clock rate of 32 MHz would command the shift registers to shift rightward, upward, or downward, and would control the MDACs. The input shift registers would be arranged in banks with eight-byte parallel input and output, so that all the input data for a full column of 64 × 64 array could be loaded in eight clock cycles.

Compaq Computer Corp., Houston, TX, has introduced enhanced models of two of its **workstations**: the Professional Workstation 5100 and 6000. The 5100 features one or two 266-, 300-, or 333-MHz Pentium II processors; maximum memory of 512 MB; five slots; five bays; and a 4-GB Wide-Ultra SCSI drive. The new version of the 6000 workstation features one or two 333-MHz Pentium II processors; maximum memory of 3 GB; six slots; 10 bays; and 10K drives.

The 3-GB maximum memory capacity is the highest in an NT workstation, enabling the system to hold large, complex models, and reduce disk swapping. New graphics accelerator options include ELSA's new GLoria Synergy with 8 MB of SGRAM for resolutions to 1920 x 1200. The Diamond Multimedia Fire GL 4000 3D graphics accelerator has been optimized for faster transfer rates and better texture mapping.

For More Information Circle No. 746

The FieldPAC™ all-metal, three-inch-thick attaché-style **portable computer** from Dolch Computer Systems, Fremont, CA, features a 15.1" TFT display, ISA/PCI expansion, and Pentium® MMX performance. The display section of the computer is designed to accommodate up to an 18.1" screen size, and can be grown in depth, independent of the main system chassis. PanelLink™ and LVDS flat-panel video communications interfaces are implemented, providing compatibility with new display technology.

The unit is housed in an aluminum-alloy enclosure that protects against shock and vibration; dust, dirt, and moisture; and electromagnetic fields. The hard drive is cushioned in a Sorbothane™ cocoon that isolates it from shock and vibration. The computer can hold a full-length ISA or PCI expansion card, plus two Type II or one Type III PC cards. It accepts power from any 90 to 265 VAC 50-60 Hz source or from a 12 VDC cigarette lighter outlet.

For More Information Circle No. 738

Cross Pen Computing Group, a division of A.T. Cross, Lincoln, RI, has introduced the CrossPad™ **portable digital notepad** that enables users to write by hand in ink on a standard pad, and transfer their handwriting directly to their PC with the press of a button. Once in the PC, the writing or drawings can be filed, reorganized, faxed, e-mailed, or printed in handwritten form or ASCII text.

Designed for use in Windows 95/NT applications, the system features an electronic pen and pad. Users take notes in ink on a standard pad of paper, while the pen transmits a signal through the paper, where the handwriting is recorded onto a digital page in the digital notepad. To access the handwriting, the user plugs the CrossPad into their PC via a cable that attaches to any standard COM port. The notepad operates on four AAA batteries.

For More Information Circle No. 741

Hewlett Packard, Palo Alto, CA, has introduced five HP Kayak **PC workstations** that feature Intel's 333-MHz Pentium® II processor. Included are three Kayak XA PC workstations for the entry-level category of Windows NT-based PC workstations, for users running 2D and business 3D graphics; a Kayak XU PC workstation that supports single- and dual-processor configurations; and a Kayak XW PC workstation that also supports single- and dual-processor configurations, and features the HP VISUALIZE fx4 OpenGL graphics subsystem.

The systems feature 64 MB of synchronous DRAM expandable to 384 MB; a 6.4 GB Ultra ATA hard disk or a 4.5 Ultra Wide SCSI hard disk; and on-board AGP graphics. They also feature HP TopTools desktop management interface PC-management software; HP LAN Remote Power for 10Base-T and 100Base-T networks; and PC hardware-monitoring features with preventative alerting.

For More Information Circle No. 736

Cherry Electrical Products, Waukegan, IL, has announced the G81-8000 (full-size) and G81-7000 (16" compact) Series multifunctional **modular keyboards** capable of reading smart cards, magnetic stripe cards, and bar codes on a single keyboard. Both models have 104 keys and are equipped with a smart card reader capable of reading/writing to any microprocessor-based and/or data storage memory card that uses protocols complying with ISO 7816. Data is exchanged between the keyboard and computer via an AT or PS/2 interface.

Also available is a magnetic card reader capable of reading any magnetic card complying with ISO 7811. Up to four tracks can be read simultaneously. The keyboards can be ordered with an integrated bar code decoder that automatically recognizes and decodes popular bar codes. GUI-based keyboard configuration software is provided to reprogram keys.

For More Information Circle No. 745

Kontron Elektronik Corp., Newport Beach, CA, offers the IN Rave **industrial notebook computer** that features a magnesium case, configurable portable IPC, a ZV port for camera connection, and the ability to add PCI frame-grabber cards. It is designed for high-impact and vibration applications in field service, industrial automation, and metrology. It is configured with Pentium® 200-MHz MMX™ processors or can be upgraded to 233 or 266 MHz.

Weighing less than 11 pounds, the notebook features an 11.3" SVGA display or an optional 13.3" XGA display. The computer's battery pack has full-operation run time of two hours, and can be extended to six hours. Two expansion bays can be configured with batteries, CD-ROM, or floppy disk drives, or combination modules. It can accept long PCI cards for frame grabbers or measurement cards.

For More Information Circle No. 735

Special Coverage: Computer Hardware & Peripherals

Panel Components Corp., Oskaloosa, IA, offers a new line of miniature Class I **grounded cordsets** rated at 2.5 amps for use with laptop computers. One end of the cordset is terminated with an IEC 320 C5 connector and the other end is terminated with an appropriate country-specific plug. Versions are available for North America, Japan, Australia, continental Europe, Britain, India/South Africa, Denmark, Sweden, Italy, and Israel.

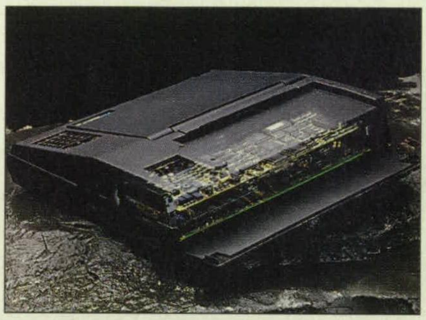
Current rating is 2.5 amps, with service at 125-250 VAC. Foreign versions are constructed with black PVC molded terminations on 3 x 0.752 mm conductor, and are available in six-foot lengths. Mating inlets and power entry modules are available.

For More Information Circle No. 742

The COMPstation U10-300 Sun Ultra 10-compatible **desktop workstations** from Tatung Science & Technology, Milpitas, CA, feature the PCI I/O bus and the 300-MHz UltraSPARCIIi PCI processor from Sun Microelectronics. The 64-bit processor supports five 32-bit PCI devices at 33 MHz; an additional 64-bit UPA slot is designed for vertical add-ons such as Creator graphics cards.

Configurations include 512 KB of external cache; 64 MB of memory, one 4.3-GB hard drive, one 1.44-MB floppy drive, and a PCI graphics card. The workstation is designed for engineering, medical research, geophysics, and other high-end applications. An add-on disk array storage subsystem boosts hard disk capacity to 80 GB and allows support of Internet or Intranet applications.

For More Information Circle No. 739



FieldWorks, Eden Prairie, MN, offers the FW7000 Series **laptop workstations** that feature an 810-MB, 100G operating hard drive; 1-MB video DRAM; sealed mousepad pointing device; two serial ports; and external PS/2-type keyboard and mouse ports. The backplane design allows for up to six ISA/PCI full-sized cards or six half-size cards, or a combination of both.

Options include batteries made up of 20 NiCd or NiMH cells; dual removable hard drives; removable hard drive under the keyboard; a backplane bracket that holds two PCMCIA cards; a 1/2-card filtered cooling fan; a ruggedized CD-ROM drive under the keyboard; and an aluminum travel case. Windows 95 on CD-ROM or 3.5" disks can be pre-installed.

For More Information Circle No. 737

The 20" Venus ATX **workstation** from Intecolor Corp., Duluth, GA, provides seven accessory card slots and a total of six drive bays. Three internal hard-drive bays house storage for massive applications and process data. Three front-access bays allow designers to load combinations such as a floppy, CD-ROM, and tape back-up unit. A sealed door covers the front-access drive bays, switches, and ports.

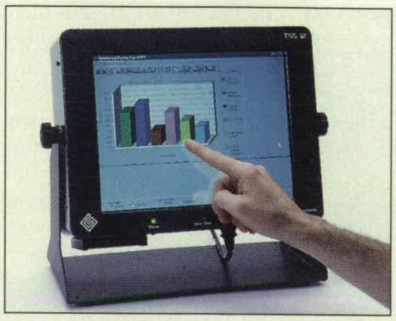
Options include NEMA 4-rated joy-stick mouse device and keypad. A panel/rack-mount chassis allows easy addition of custom controls. The workstation is designed for handling large databases, detailed graphics, and large number sets.

For More Information Circle No. 743

The 96 Series **sealed keyboard/trackball** from Computer Keyboard Systems, Santa Monica, CA, is compatible with IBM AT/PS2, DEC, RS-232, and other standard computers. The low-profile keyboard/trackball unit, in cased or uncased configurations, meets NEMA 4/4X standards, and is available in the standard 96-key version.

The mechanical keyswitches, rated at more than 20 million cycles, are protected by a 2-mm-thick steel plate with a wear- and chemical-resistant polyester front sheet and overall moisture-protection sealing. Faraday Cage construction ensures compliance with EMC/EMI requirements. The unit is adaptable to vertical panel mounting, and can be fitted into an 18" rack system. Versions with 42, 128, and 168 keys are available.

For More Information Circle No. 740



Greco Systems, El Cajon, CA, has introduced the TSS-12 color **touchscreen computer** with a 12.1" 800 x 600 SVGA display. The fully integratable PC is designed to accommodate shop floor environments, and features a 300 NIT monitor. The unit also features a Media GXi 200-MHz processor. It comes with external keyboard and printer ports, but is designed for keyboard- and mouse-free operation of Windows-based programs.

The screen responds to fingertip input and is resistant to most chemicals and solvents. It is equipped with a fan and filtration system designed to cool the system and protect it from harmful debris. The swivel base can accommodate tabletop or machine-side placement. The unit utilizes PC/104 technology and can be integrated into Token Ring or Ethernet local area networks.

For More Information Circle No. 744

DC-Excited Thermostrain-Gauge Signal-Conditioning Circuit

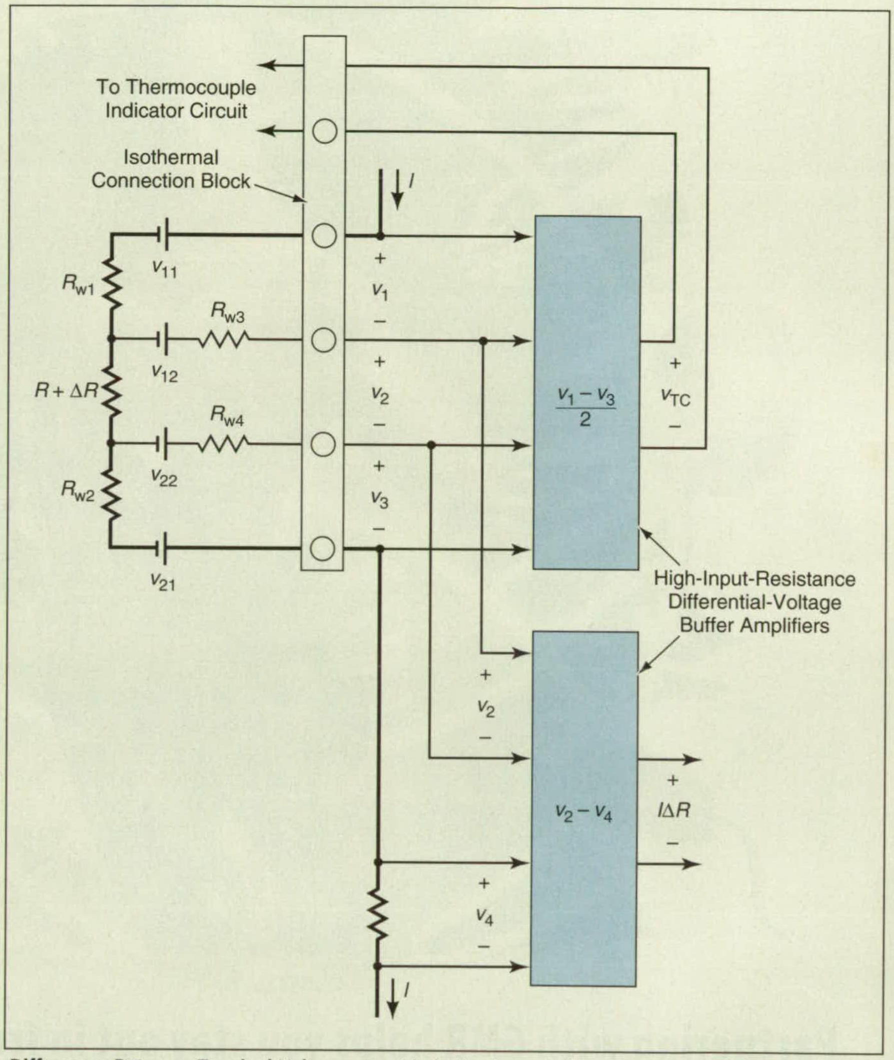
Gauge-resistance and temperature signals are separated.

Dryden Flight Research Center, Edwards, California

The figure illustrates a dc-excited Anderson-loop circuit that includes (1) thermocouples for measuring the temperature of the strain gauge and (2) a signal-conditioning circuit that separates the temperature and strain-gauge signals in the sense that one output voltage is proportional to the change in the strain-gauge resistance and another voltage is proportional to the thermoelectric voltage indicative of the temperature of the strain gauge.

The concept of the Anderson loop was discussed previously in three articles in *NASA Tech Briefs*; namely, "Constant-Current Loops for Resistance-Change Measurements" (ARC-11988), which appears elsewhere in this issue; "The Anderson Current Loop" (DRC-00001), Vol. 18, No. 12, (December 1994), page 30; and "Patent Statement on the Anderson Current Loop" (ARC-13376), Vol. 20, No. 11 (November 1996), p. 12a. To recapitulate: In the basic Anderson current loop, voltage drops in lead wires are excluded from measurement by use of the well-known Kelvin technique, in which a known current is supplied via two lead wires to a resistance to be determined, the voltage across this resistance is coupled to a high-input-resistance voltmeter via two other lead wires, and the voltage drops in these voltage-measurement lead wires can be neglected because they carry negligible current by virtue of the high input resistance of the voltmeter.

Here, a known constant current I is supplied to a strain gauge of resistance $R + \Delta R$, (where R is an initial value and ΔR is a change caused by the combined effects of strain and temperature). The strain-gauge resistance is connected in series with two thermocouple wires of resistance R_{w1} and R_{w2}, respectively. These wires are both made of the same one of two thermocouple alloys and are of the same length, so that $R_{w1} = R_{w2}$. Two other wires (R_{w3} and R_{w4}) made of the other thermocouple alloy, are connected to the terminals for measuring the voltage drop in the strain-gauge resistance. A reference resistor ($R_{ref} = R$) at a reference or ambient temperature is also connected in series with the strain-gauge resistance.



Differences Between Terminal Voltages provide indications of the temperature of the strain gauge and the change in the strain-gauge resistance.

The thermoelectric voltage of thermocouple (R_{w1},R_{w3}) is given by

$$v_{TC1} = v_{11} - v_{12};$$

the thermoelectric voltage of thermocouple (R_{w2},R_{w4}) is given by

$$v_{TC2} = v_{21} - v_{22}.$$

The thermoelectric-output-voltage level of each thermocouple represents the temperature of its connection to the strain gauge.

Straightforward algebraic manipulation of the equations that relate the terminal voltages v_1 through v_4 with the voltage drops in the various resistances and with the thermoelectric voltages yields the following equations for the desired output voltages:

$$v_{TC} = (v_1 - v_3)/2 \text{ and}$$
$$I\Delta R = (v_2 - v_4).$$

As indicated in the figure, the terminal voltages v_1 through v_4 are coupled to Anderson subtractors comprised of buffered differential level shifting amplifiers wired to implement these equations. The subtractor outputs are then the out-

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• Ohms range	nΩ – TΩ	nΩ – TΩ	nΩ – TΩ	nΩ – TΩ
• Frequency range	DC to 2GHz	DC to 2GHz	DC to 200MHz	DC to 200MHz
• Scanning speed	Up to 225 ch./s	Up to 400 ch./s	200 setups/s	200 setups/s
• Card slots	2	10	6	1
• Main display	VFD	VFD/LED	LED	LED
• Memory locations	100	500	100	100

For More Information Circle No. 589

put thermoelectric voltage v_{TC} and resistance-change voltage $I\Delta R$.

This work was done by Karl F. Anderson of Analytical Services and Materials for **Dryden Flight Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category,* ***or circle no. 165*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

DRC-96-10

Lightweight, Radiation-Resistant EMI Shields

Effective shielding can be achieved at fractions of the weights of aluminum boxes.

Lewis Research Center, Cleveland, Ohio

Due to their low density and exceptionally high strength and modulus, graphite fiber composites are being used increasingly for the fabrication of aircraft and spacecraft. Because of their superior mechanical properties, these composites have been replacing metals, such as aluminum alloys, in many applications. The replacement of metals has been slow, however, when high electrical conductivity is needed because of the relatively poor electrical conductivity (< 0.1 percent of metals) of composite materials. Designers have also shied away from graphite-polymer composites in applications where shielding from ionizing radiation is important, because of the poor performance of these composites.

These shortcomings of graphite-fiber polymer composites can be addressed by intercalating the fibers before fabricating the composites. Intercalation is the insertion of guest atoms or molecules (intercalates) in between the carbon layers of the fibers. If the intercalate is chosen carefully, the electrical conductivity of the composite can be increased nearly an order of magnitude, and the specific radiation shielding can surpass low density metals.

Two intercalates, bromine and iodine monobromide, have been shown to have the right combination of properties to make them commercially viable options. They combine the virtues of high electrical conductivity, high thermal conductivity, and good radiation shielding with excellent stability and easy processibility.

Bromine has been shown to intercalate a wide variety of pitch-based and vapor-grown graphite fibers. Most of the research has centered around Amoco's Thornal fibers. Bromine has been shown to enhance the conductivity of P-55, P-75, PO-100, P-120, and K-1100 fibers by a factor of three to six. The resulting material has an electrical conductivity surpassing that of stainless steel. Furthermore, these intercalation compounds are stable to temperature well above the processing temperature for most resins, and are impervious to moisture and ultra-high vacuum. Fabrication of composites from intercalated fibers does not degrade their

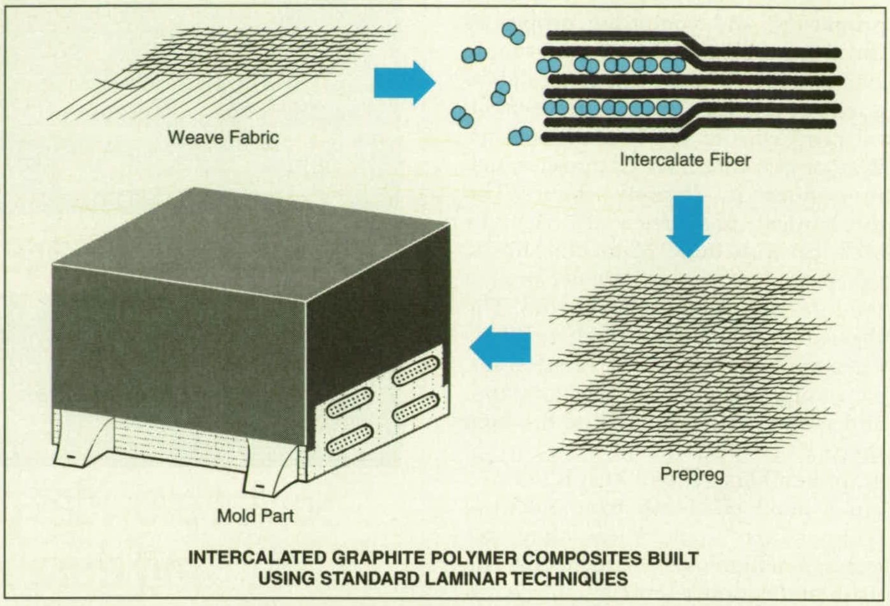
properties, and composite properties can be predicted by using a simple rule-of-mixture. Although intercalation does not enhance either the mechanical properties or the thermal conductivity of graphite fiber composites, neither does it degrade them. The mechanical properties are virtually identical with those of pristine fibers, except that there is an enhancement in the interlaminar shear properties. The thermal conductivities of these fibers are among the highest of all materials, exceeding such metals as aluminum and copper. Also, because of the high thermal absorption and emissivity of graphite fibers, radiant heat is rejected much more efficiently from electrical components than when they are encased in highly reflective metals. The mass absorption coefficient for ionizing radiation by composites made from intercalated fibers is enhanced by a factor of four, to a value exceeding that of aluminum.

Iodine monobromide has not been studied as extensively as bromine has as an intercalate for graphite fibers. Those studies that have been done reveal intercalation compounds nearly identical with those utilizing bromine. The exception is in the mass absorption coefficient for ionizing radiation, which is nearly twice that of bromine intercalation compounds, and three times that of aluminum. The implication is that iodine monobromide intercalated fiber composites can provide radiation shielding equal to that of aluminum with one-third the mass.

The primary application envisioned for this technology is electromagnetic interference (EMI) shielding of electronics. Calculations indicate that the shielding effectiveness of these composites, while not as high as that of aluminum, is higher than the requirements for many applications, and higher than that of joints and penetrations through metallic boxes. Experimental studies confirm the high shielding effectiveness calculations. The surface conductivity, while not as high as that of metals, is high enough that no special surface treatments (sanding off the surface polymer layer, etc.) are required. These materials can be used effectively with conventional EMI shielding gasketing strategies.

The total achievable mass savings depends on the particular requirements of the shield. If the limiting factor is shielding from high-energy radiation, a mass savings of 66 percent is achievable. If the limit is strength, 86 percent of the mass can be saved. Finally, if the limit is stiffness (modu-

lus), over 90 percent of the mass can be saved. The implications for such weight savings can be dramatic. In spacecraft, because the payload is a smaller portion of the spacecraft than the power and communications systems, the payload may be increased by as much as 40 percent. In communications satellites, the mass savings could be taken up in attitude-control fuel, extending the useful lifetime of the spacecraft. In some cases, it could enable the launch by smaller and cheaper launch vehicles. In aircraft, decreased weight would allow for fuel savings, which, when figured over the life of the aircraft, could be substantial. For consumer products, such as notebook computers and cellular telephones, lower weight itself might be a significant selling point.



Intercalated Graphite Polymer Composites are built using standard laminar techniques.

This work was done by James R. Gaier of **Lewis Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category,* ***or circle no. 124*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

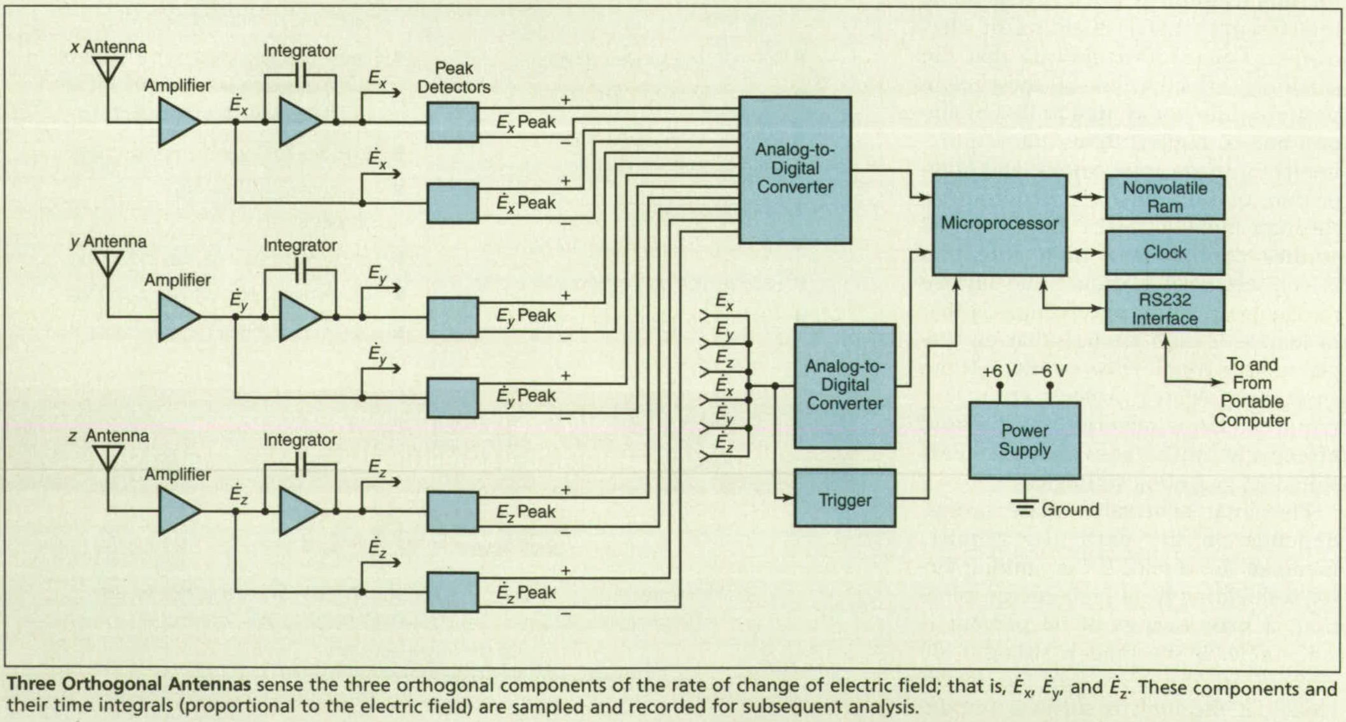
Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16535.

Instrument Records Electric Fields Generated by Lightning

This instrument complements another instrument that measures magnetic fields generated by lightning.

John F. Kennedy Space Center, Florida

A portable, self-contained, compact instrument measures and records transient electric fields generated by nearby lightning strikes. This instrument complements, and in many respects is similar to, the one described in "Instrument Records Magnetic Fields Generated by Lightning" (KSC-11769), *NASA Tech Briefs*, Vol. 19, No. 4 (April 1995), page 38. Both instruments are designed to be placed near sensitive electronic equipment before thunderstorms



Three Orthogonal Antennas sense the three orthogonal components of the rate of change of electric field; that is, $\dot{E}_x$, $\dot{E}_y$, and $\dot{E}_z$. These components and their time integrals (proportional to the electric field) are sampled and recorded for subsequent analysis.

begin. The data recorded by the instruments during thunderstorms can be analyzed afterward to determine whether the electromagnetic fields associated with the lightning were strong enough that they might have damaged and/or affected the operation of the sensitive equipment. Thus, the instruments provide data that can be used in deciding whether the sensitive equipment should be tested for damage and/or other effects caused by lightning. Typical installations in which the instruments could prove beneficial include outdoor sensing equipment, computer rooms, broadcasting stations, and powerplant-control rooms.

The present instrument (see figure) includes three orthogonal antennas on an electrically conductive sphere. Each antenna senses one of the three orthogonal components of the transient electric field. The current $i(t)$ induced in each antenna is proportional to the rate of change of the electric-field component $E(t)$, and is given by

$$i(t) = kA\varepsilon\frac{\partial E}{\partial t}$$

where t is time, A is the area of the antenna, ε is the permittivity of air (very close to ε_0, the permittivity of the vacuum), and k is a constant that expresses the concentration of the electric field in the vicinity of the antenna or a similar electrically conductive object. The spherical shape was chosen because k for a sphere is easily determined and is found to equal 3.

In the instrument, the currents are measured to determine the rates of change of the components of the electric field. The current signals are also integrated to obtain signals proportional to the electric-field components.

The instrument includes a microprocessor that controls its overall operation. It also includes an analog-to-digital converter and a sampling clock. Under control by the microprocessor, the analog-to-digital converter samples the waveform of one component of the electric field at a rate of 10 MHz for a duration of 50 μs. (The reason for not sampling all three waveform components is simply that doing so would consume too much power.) Also under control by the microprocessor, the peak values of all three components of the electric field and their time derivatives are sampled and compared with specified threshold levels during intervals of 1 ms. The electric-field waveform sample values and their times are stored in a nonvolatile random-access memory (NVRAM). The peak electric-field and derivative sample values that exceed the threshold levels, and their times, are also stored in the NVRAM.

The stored values are subsequently read out by use of a portable computer. The instrument is powered by batteries and can operate unattended for as long as two weeks. The inclusion of the NVRAM prevents the loss of data in the event of a power failure. The batteries can be changed in the field, so that the instrument can remain in place and continue to measure the electric field without interruption.

With their 10-MHz sampling rate, both this instrument and the previously reported magnetic-field instrument measure electromagnetic fields generated by lightning more accurately than do portable commercial magnetic-field meters. Lightning waveforms typically include frequencies up to tens of megahertz, while the commercial meters, which are designed to measure magnetic fields of high-voltage power lines, are usually limited in frequency response to a few hundred hertz.

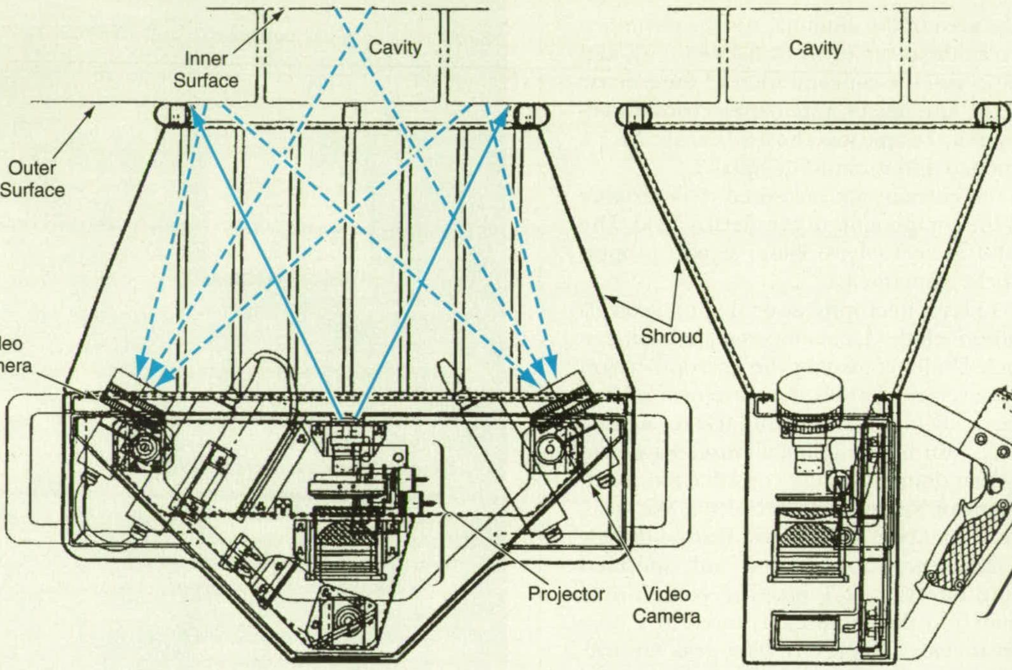
This work was done by Pedro J. Medelius and Howard James Simpson formerly of I-Net for **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category,* ***or circle no. 156*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
KSC-11953

Optoelectronic System Measures Tile Cavities

Three-dimensional measurement of a cavity is accomplished in less than one second.

John F. Kennedy Space Center, Florida

A hand-held optoelectronic shop tool measures cavities of the order of 6 in. (15 cm) in length and width, 2 to 4 in. (5 to 10 cm) in depth, with nominally flat side walls, and either curved or flat outer and inner surfaces. The system is called the Tile Cavity Measurement System (TCMS) because in the initial application for which it was developed, the cavities are those created by removal of space shuttle insulating tiles. In that application, the



OPTICAL LAYOUT

HAND-HELD TOOL IN USE

Using a Hand-Held Shop Tool that contains a camera and a projector, the technician measures a tile cavity in less than 1 second. Previously, it was necessary to make and use a plaster model in a tedious, messy process that took as long as 30 hours and yielded marginal accuracy.

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data acquired by the system are used in computer-aided design (CAD) and in computer-aided manufacturing (CAM) of new tiles to fit in the cavities. The system can also be used to measure other cavities of similar size and shape.

The hand-held optoelectronic shop tool (see figure) contains a white-light projector that illuminates the surfaces of the cavity with a pattern of stripes. Two high-resolution video cameras mounted on opposite sides of the projector are aimed toward the sidewalls and inner surfaces of the cavity to facilitate viewing the cavity sidewalls from different angles. The reason for using two cameras is simply that one camera would not suffice to view all cavity surfaces. The combined field of view of the cameras is an area of about 10 in. (25 cm) square, which includes the side walls and inner surface of the cavity plus the surrounding outer-surface area. The projector and cameras are connected by a 30-ft (9-m) cable to a mobile workstation, which includes a computer, video display, and the control and interface electronics. The projector and cameras operate under control by the computer, and the outputs of the cameras are digitized and sent to the computer for analysis.

The projector and cameras are mounted on a rigid frame, which includes a shroud that keeps out background light and also serves to stabilize the tool against the cavity outer surface during measurements. The hand-held unit is equipped with handles and a pistol grip for positioning and control. On the pistol-grip handle are menu-selection thumb buttons and a trigger switch to initiate the measurement. A small color video monitor attached to the pistol-grip handle displays menus, video images of the measurement scene, and data.

The projector system includes a solenoid-operated translation stage with a striped pattern mounted on it. In operation, the video cameras acquire a set of four images of the pattern, each translated 1/4 of the stripe width. The entire measurement of a cavity takes less than 1 second. The shifted-stripe-pattern data are then processed by established phase-shifted-fringe-measurement techniques to obtain data from which the cavity surfaces are reconstructed in three dimensions. The data are stored and transferred to other computers in International Graphics Exchange Specification (IGES) format. The data can also be printed.

This work was done by Edward D. Huber and Rick A. Williams of Lockheed Martin Missiles & Space Co. for **Kennedy Space Center.** *No further documentation is available.*

Title to this invention, covered by U.S. Patent No. 5,561,526 has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457 (f)]. Inquiries concerning licenses for its commercial development should be addressed to

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Lockheed Martin Missiles &
Space Co., Inc.
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Advanced Technology Center
3251 Hanover St.
Palo Alto, CA 94304
(650) 424-3308

Refer to KSC-11727, volume and number of this NASA Tech Briefs *issue, and the page number.*

Estimating Attitude From GPS Measurements on One Antenna

The antenna boresight direction can be estimated to within approximately ±15°.

NASA's Jet Propulsion Laboratory, Pasadena, California

A technique for estimating the boresight direction of a Global Positioning System (GPS) receiver antenna involves utilization of the relationship between the strengths of received signals and the direction-dependent antenna gain pattern. The technique is fundamentally different from, and much less precise than, other attitude-determination techniques based on interferometry with multiple antennas. The major advantage of this technique is that it quickly gives a coarse estimate, using data from only one antenna. The coarse estimate is not suitable for fine-attitude applications like aiming a telescope or a laser beam, but it can be used, for example, to guide the orientation of a broad-beam communication antenna, to aim a solar panel, or to initialize a fine attitude-determination algorithm or instrument.

The technique is most easily practiced in the case of an antenna with a broad radiation pattern in which the gain decreases monotonically with increasing angle off boresight. The GPS receiver used in this technique must be one that generates data on the signal-to-noise ratio (SNR) of the signal received from each GPS satellite that it tracks. Once the GPS receiver has computed its position from the received GPS signals, the direction to each tracked GPS satellite is known as a byproduct.

The SNR of the signal received from each tracked GPS satellite is taken as a crude measure of the relative strength of the signal and, as such, is used as a weighting value to obtain a vector sum: The unit vector in the known direction to each tracked satellite is multiplied by the SNR for that satellite. The sum of such scalar·vector products for all the tracked satellites is a vector, the direction of which is taken to be the estimated antenna boresight direction. The length of the vector also constitutes ancillary information about the geometric properties of the constellation of tracked GPS satellites.

If only one GPS satellite is being tracked, then the estimated boresight points directly at that satellite; such an estimate is usually erroneous, but it could be helpful in finding other satellites to track and thus obtain a better estimate. When six to eight GPS satellites are being tracked, the estimated boresight differs from the actual boresight by no more than about 15°.

This work was done by Charles Dunn and Courtney Duncan of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category,* ***or circle no. 107*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20323

Software

Application Specific Integrated Circuit Physical Layout for the RSDL ASIC

An integrated circuit physical layout has been developed for the RSDL ASIC — an integrated circuit that encodes telemetry data and transfers the data (which are grouped together in transfer frames) to a radio transmitter. The RSDL ASIC is described in "ASIC for Reed-Solomon Coding and Related Functions" (NPO-19614), which appears elsewhere in this issue of *NASA Tech Briefs*. The present physical layout will be converted to mask for IC fabrication of the RSDL ASIC. The physical layout has been extensively simulated for its timing, control, bus-arbitration, encoding, and data-transfer functions, which have been summarized in the noted prior article.

This work was done by James A. Donaldson, Steven H. Wood, and Huy H. Luong of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category,* ***or circle no. 115*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Refer to NPO-19626, volume and number of this NASA Tech Briefs *issue, and the page number.*

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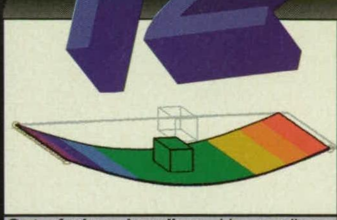
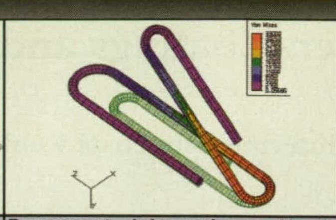
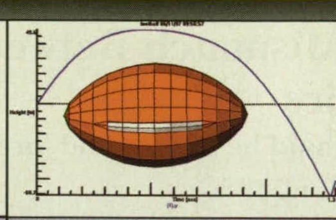


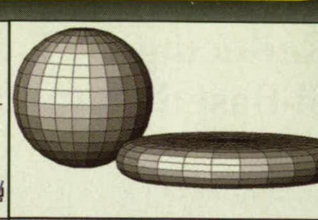
Out of plane bending - Use nonlinear analysis to determine whether this plate will foreshorten and fall out of its support. Linear cannot predict geometry changes perpendicular to a load.



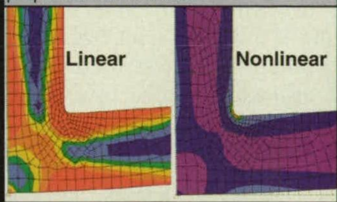
Permanent deformation - Algor's nonlinear analysis can predict the permanent deformation when the predicted stress exceeds the yield stress. Linear analysis can't do this.



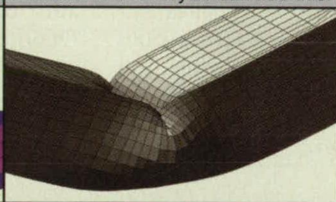
Trajectory - Basic motion, such as the trajectory of this rotating football is easily done using Algor's nonlinear analysis. Linear analysis cannot predict motion.



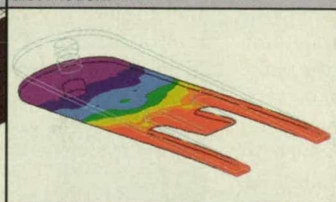
Squashing - Squashing this rubb ball in a vise using linear analys cannot predict the final shape like th nonlinear analysis.



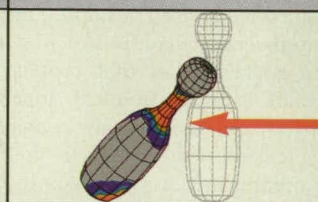
Stress concentration - Linear stress analysis will misrepresent both the stress and the deformation of this hanger due to minute changes in the fillet. Nonlinear analysis gets it right.



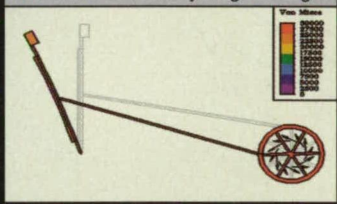
Local buckling - When failure is due to local buckling, the geometry fails at stresses much, much lower than the yield stress. Linear cannot detect local buckling.



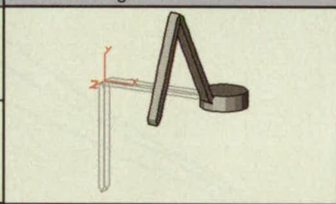
Snap-through - Any time you have a snap-through effect, your part is in motion until it stops on the other side. You need nonlinear analysis to predict this effect.



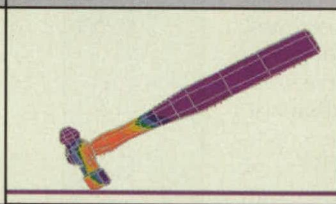
Impact - Nonlinear dynamic respon predicts the stress in an object wher goes into motion as a result of impact another object. Linear analysis cann analyze for impact and motion.



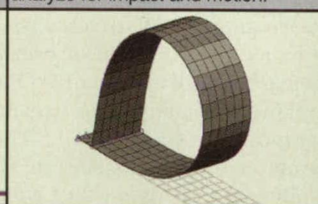
4-bar link - Linear dynamic analysis cannot predict the forces and stresses due to periodic loading. Accupak/VE simulates the loading and stresses in one analysis.



3-D mechanism - When a moving object is a 3-D mechanism, high inertia forces can occur. You need Accupak/VE to predict the stresses caused by motion.



Contact impact - Kinematic motion and the stresses due to the shock of impact cannot be predicted by either linear stress analysis or kinematics analysis software. Accupak/VE does it in one shot..



Elastic large deformation - Nonline analysis predicts the stressed geome when the deformation is significa even if the material properties rema linear. Linear analysis fails at this.

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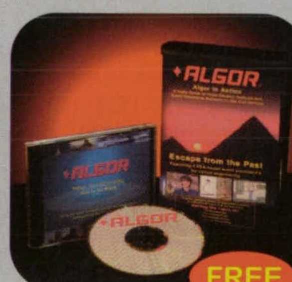

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Reducing CTE Mismatch Between Coatings and Si-Based Ceramics

Coating compositions would be altered and/or intermediate coats would be used.

Lewis Research Center, Cleveland, Ohio

Two techniques have been proposed to reduce thermal-expansion mismatches between (a) substrates made of silicon, silicon-based ceramics, and silicon-based-ceramic composite materials and (b) surface coats that protect the substrates against chemical attack in oxidizing and/or corrosive environments. Typical substrate materials include SiC/Si composites. A typical coating material is mullite ($Al_6Si_2O_{13}$), which can protect silicon-based substrates against water-free oxidizing and corrosive environments. Mullite can also be applied as intermediate coating layers to relax stresses and enhance the adhesion of overlying protective layers of zirconia (ZrO_2) or nonstoichiometric anorthite (stoichiometric composition $CaAl_2Si_2O_8$). The coefficients of thermal expansion (CTEs) of mullite and of some other typical oxide coating materials are greater than the CTEs of silicon-based substrates and, as a result, the coatings tend to crack through their thicknesses. The cracks become pathways for the entry of the chemical species from which one seeks to protect the substrates.

In one proposed technique, one or more lower-CTE phase(s) would be incorporated into a mullite coating to reduce the CTE of the coating for a better CTE match with the substrate. Suitable lower-CTE compounds include cordierite ($2MgO.2Al_2O_3.5SiO_2$) and fused silica (see Figure 1). Mullite, cordierite, and fused silica would be chemically compatible with the substrate, with each other, and with typical other oxide coating materials. A composite coating of mullite with cordierite and/or fused silica could be applied by plasma spraying or by a wet chemical process.

The CTE of a polycrystalline material like a mullite/cordierite/fused silica composite can be approximated by a rule of mixtures: $\alpha_c \approx \sum \alpha_i V_i$, where α_c is the CTE of the composite, α_i is the CTE of the *i*th constituent, and V_i is the volume fraction of the *i*th constituent. Initially, the proportions of cordierite and/or fused silica could be chosen to obtain a desired value of α_c according to this rule. However, because of the complexity of the phase composition of the mullite/cordierite/fused silica system, a process of trial and error would likely be necessary to establish the optimum composition.

In the second proposed technique, zircon ($ZrSiO_4$) would be applied as an intermediate layer between a substrate and an overlying protective coating. Optionally, if a dense, crack-free zircon coating could be produced, then it could be used, instead of mullite, as a protec-

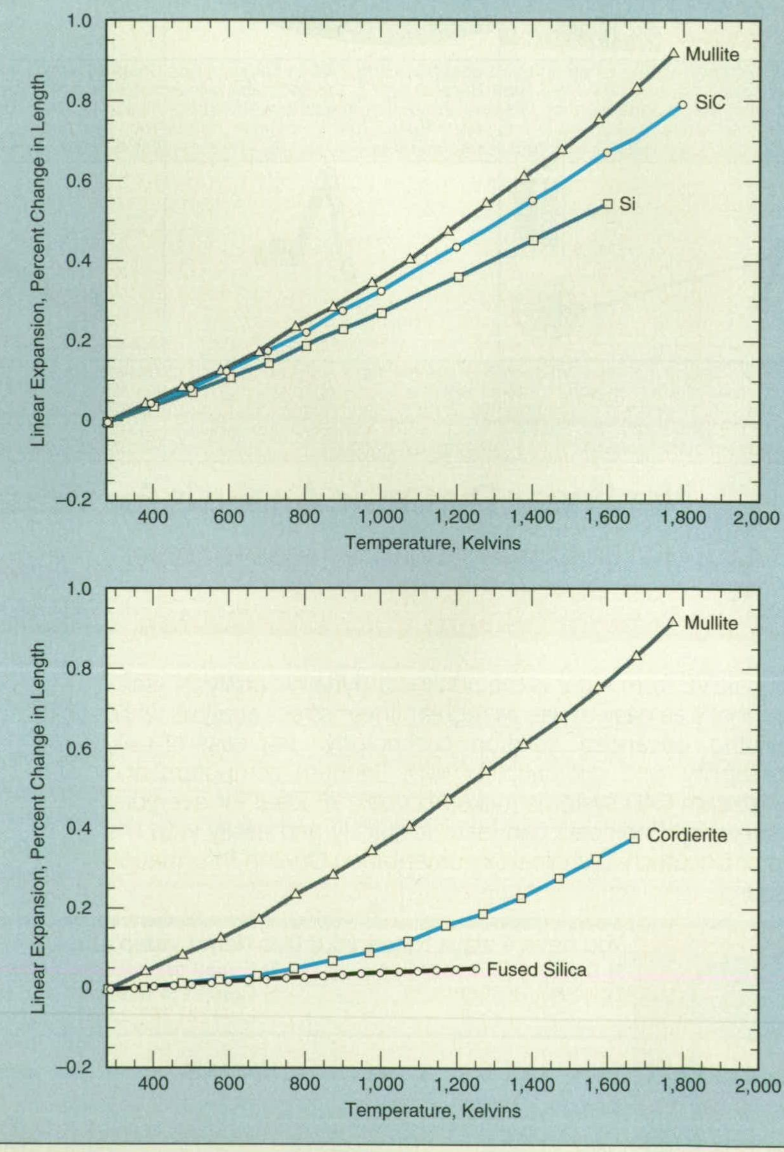

Figure 1. **Mismatches Between Thermal Expansions** of mullite and of Si and SiC are large enough to cause cracking of mullite coatings on Si-based substrates. Thermal-expansion mismatch can be reduced by incorporating the lower-thermal-expansion material(s) cordierite and/or fused silica into a mullite coating.

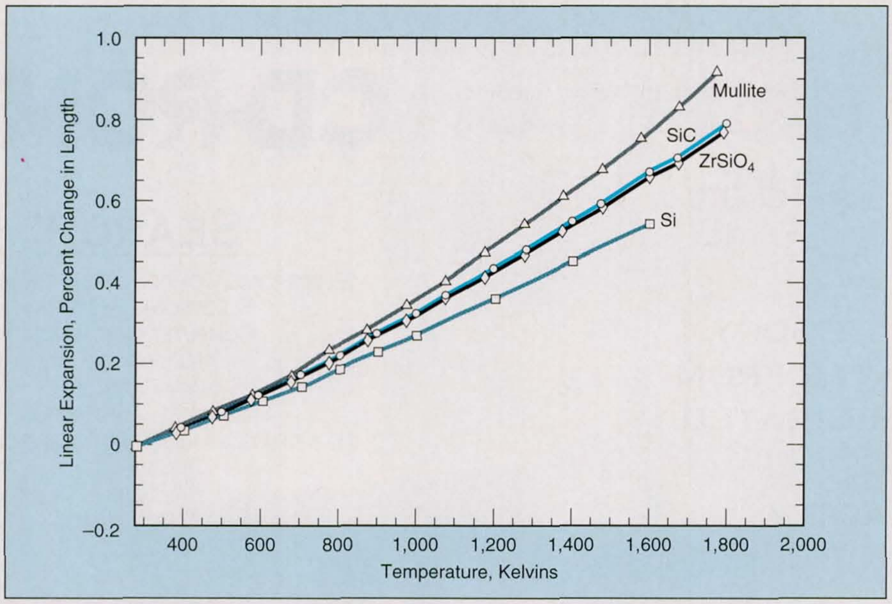

Figure 2. The **Thermal Expansion of Zircon** matches the thermal expansions of Si and SiC more closely than does the thermal expansion of mullite.

tive coating, provided that there is no water vapor in the environment. In comparison with mullite, zircon has a CTE closer to the CTEs of the typical substrate constituents SiC and Si. If resistance to water is needed, then a protective coating of zirconia (ZrO_2) or of various silicates could be applied over the zircon layer. Zircon would be chemically compatible with both the protective coating and the thin layer of SiO_2 that typically forms on the surface of an Si-based substrate.

Like a mullite/cordierite/fused silica composite coating, a zircon coating could be applied by plasma spraying or by a wet chemical process. Plasma spraying could be complicated by the fact that zircon melts and freezes incongruently, forming cubic zirconia first upon cooling from the liquid phase. It might be necessary to add Y_2O_3 or CaO to the starting composition to stabilize the cubic phase and prevent volumetric changes while allowing the conversion to zircon to take place. Post-spray annealing might be necessary to help the zircon coating reach equilibrium and enhance its stability.

The CTE of zircon is slightly less than that of SiC, though greater than that of Si(see Figure 2). In the case of zircon plasma-sprayed on SiC, the slight difference between the CTEs results in a small compressive stress in the zircon. Inasmuch as the compressive strength of zircon exceeds its tensile strength, this small compressive stress could be advantageous in that it might offset small residual local tensile stresses and thereby help to prevent cracking. As in the first technique, one could incorporate lower-thermal-expansion phases like cordierite and/or fused silica to obtain a lower overall CTE; for example, to obtain a greater compressive stress in a coating on an SiC substrate or to obtain a closer CTE match with an Si substrate.

This work was done by Hongyu Wang of General Electric Co. for **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 103*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Single Crystal Nickel-Base Superalloy

Modified turbine-blade alloy resists fatigue and crack growth.

Marshall Space Flight Center, Alabama

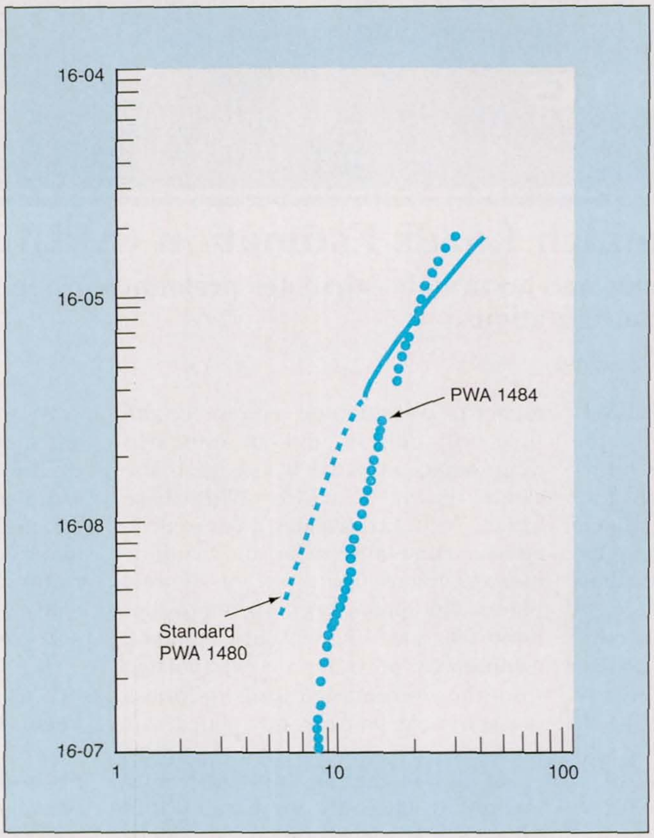
A modified alloy, known as Modified PWA1484, is a single-crystal nickel-base superalloy, developed under a NASA Marshall Space Flight Center contract for use as a turbine blade and vane alloy for the space-shuttle main engine (SSME). This alloy is a modified PWA 1484 composition that uses innovative thermal-process techniques to generate a

microstructure specifically tailored for SSME application. The superalloy exhibits significantly better fatigue and crack-growth resistance than previous turbine-blade alloys (such as PWA1480), particularly under severe hydrogen-embrittling conditions.

When compared to the conventional alloy PWA1480, Modified PWA1484 had a high cycle fatigue life that is 100 times greater than PWA1480. Fatigue strength for the new single-crystal nickel-base superalloy was approximately 30 ksi (207 MPa) higher than the previous turbine-blade material.

In other tests, the smooth low cycle fatigue life for PWA1480 was compared to the Modified PWA1484. Fatigue life for the superalloy was more than an order of magnitude greater than PWA1480.

Additionally, this single-crystal nickel-base superalloy was compared against PWA1480 in notched low cycle fatigue. Modified PWA 1484 proved to be 3 to 10 times greater than PWA1480 in notched low cycle fatigue.



Modified PWA1484 has significantly better fatigue resistance in the critical near-threshold region of the fatigue-crack-growth curve than conventionally used material.

When tested for fracture resistance, the Modified PWA 1484 was significantly better in the critical near-threshold region of the fatigue-crack-growth curve than PWA1480. (The results of this test can be seen in the illustration.)

These comparisons show that alloys, such as this single-crystal nickel-base superalloys, will provide better turbine blades and vanes for space-shuttle components, such as high-pressure fuel and oxidizer turbopumps.

This work was done by Daniel P. DeLuca, Charles M. Biondo, and Barrie J. Peters of United Technologies Pratt & Whitney for **Marshall Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 153*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). MFS-31203*

Automated PreLaunch Loads Estimation (APLLE)

A computer program quickly and accurately calculates prelaunch ground-wind loads for different launch-vehicle configurations.

Marshall Space Flight Center, Alabama

Over the past year, the Structural Dynamics and Loads Branch of Marshall Space Flight Center has been calculating prelaunch ground winds for several different launch-vehicle configurations. Engineers developed a computer programming system to streamline the analysis cycle.

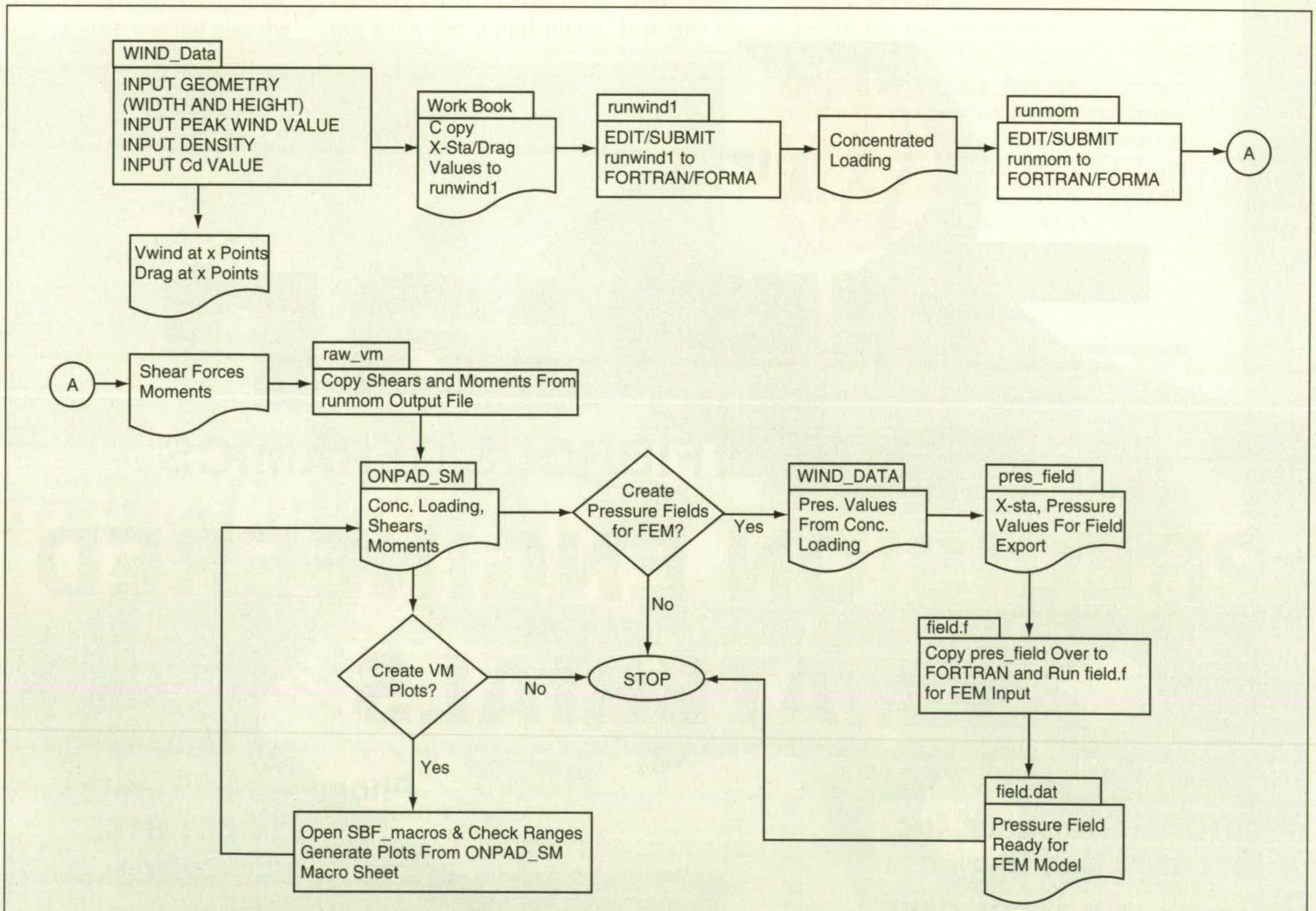
This documented procedure, known as Automated PreLaunch Loads Estimation (APLLE), uses a spreadsheet, word processor, and FORTRAN computer programs to provide quick and accurate load estimations. APLLE can easily be adapted for structures other than launch vehicles.

APLLE combines the input of structure geometry (width and height), a reference peak-wind value, a reference altitude and density, and an estimated drag-coefficient value based upon the shape of the structure. With these inputs, APLLE calculates a concentrated load, cumulative shear, and bending-moment values for a set of discrete points. The spreadsheet macro provides rapid diagrams of shear and moment. Additionally, pressures are extrapolated from the concentrated loads to form a pressure field that can be applied to a finite-element code.

For a free-standing structure, wind loading is the only forcing function other than gravity acting on the vehicle. Calculation of these wind loads assumes the wind load acts as a steady-state load.

Wind loading is divided into two parts: the drag load and the vortex-shedding load. The drag load is assumed to act parallel to the wind vector, and the vortex shedding acts normal to the wind vector. An uncertainty factor of 1.5 is applied to the wind loads to account for vortex shedding and gusts.

This work was done by Samuel B. Fowler and Joseph Brunty of the **Marshall Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category,* ***or circle no. 192*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
MFS-31149



The **Automated PreLaunch Loads Estimation (APLLE)** procedure provides quick and accurate load estimations for a variety of structures.

The Modified Fully Utilized Design Method

Solutions are comparable to those obtained by nonlinear optimization techniques.

Lewis Research Center, Cleveland, Ohio

The modified fully utilized design (MFUD) method is undergoing development for use by engineers who favor traditional methods of designing structures over methods based on advanced calculus and nonlinear mathematical programming techniques. Thus far, the MFUD has been developed for trusses, with cross-sectional areas of truss members as design variables. Like nonlinear optimization methods, the MFUD method is iterative, but in comparison with those methods, the MFUD method involves less and simpler computation.

The MFUD method is derived from the fully stressed design (FSD) and fully utilized design (FUD) methods. The FSD method, based on a simple stress-ratio approach, is popular in civil, mechanical, and aerospace engineering. The FSD method is an elegant conceptual tool for arriving at stress-limited designs, but does not provide for displacement constraints, which are imposed with increasing frequency in designing modern structures.

An extension of the FSD method through provision for displacement constraints in addition to stress constraints yields the FUD method. The term "fully utilized design" signifies a design in which the number of active constraints equals or exceeds the number of design variables. One obtains the FUD of a structure by the following procedure:

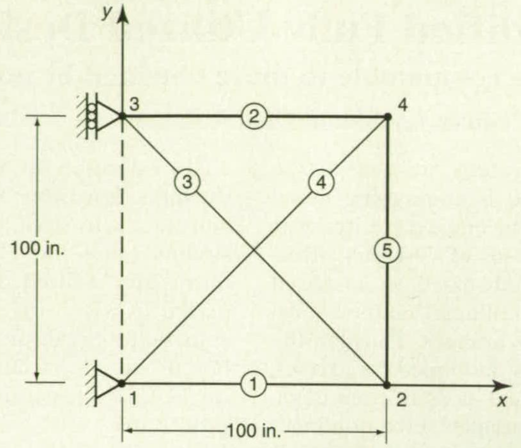
1. Using the stress constraints only, generate the FSD.
2. Uniformly prorate the FSD to obtain the FUD, using a constant proration factor that satisfies the single most infeasible displacement constraint. For a truss structure, this entails multiplying the cross-sectional areas of all truss members by the same factor to strengthen all the members enough to limit the displacement, as required.

The FUD thus obtained is feasible but can be an overdesign; the weight of the FUD structure can be greater than that of an optimally designed structure.

The MFUD method accommodates both stress and displacement constraints simultaneously. The steps of this method applied to a simple truss structure are the following:

1. Identify the design variables to initiate iterations. Optionally, one can begin iterations from the FSD. For subsequent iterations, the stress constraints are expressed in terms of cross-sectional areas, given by
$$A_i = (F_i)_{max}/\sigma_{i0},$$
where Ai is the area in question for the ith member, $(F_i)_{max}$ is the maximum force in ith member under all loading conditions, and σ_{i0} is the maximum allowable stress in the ith member.
2. Identify the displacement constraints violated by the design obtained in step 1.
3. For each displacement constraint identified in step 2, update the design independently to satisfy the constraint. The update process comprises two subprocesses: (1) identifi-

For More Information Circle No. 429



FIVE-BAR TRUSS

Results	MFUD	FUD	SUMT	OC
Optimum Weight, lb	44.817	62.228	45.029	45.016
Member Area, in.^{2}:				
A_1	0.001	1.068	0.001	0.001
A_2	1.475	1.068	1.501	1.499
A_3	0.001	1.068	0.001	0.001
A_4	2.124	1.068	2.119	2.120
A_5	0.001	1.068	0.001	0.001

DESIGN RESULTS

A **Five-Bar Truss** subject to one load and one displacement constraint was designed by the MFUD and FUD methods and by two optimization methods called "SUMT" and "OC." In this case, the FUD design was about 39 percent too heavy, while the MFUD design was even lighter in weight (more nearly optimum) than were the SUMT and OC designs.

cation of a subset of design variables pertinent to that constraint and (2) computation, for each member, of a member-weighted parameter, which is a multiplicative parameter based partly on the sensitivity of the constraint-violating displacement to the cross-sectional area of the member. The member-weighted parameter supplants the constant proration parameter of the FUD method. The equations used in these subprocesses are derived from the integrated force method, which was described in "Constructing Finite Elements for the Integrated Force Method" (LEW-16421), *NASA Tech Briefs*, Vol. 21, No. 7 (July 1997), page 70.

4. Obtain the design update for the structure as the union of all of the designs updated for the constraints in step 3. If any member is affected by more than one of the constraint-updated designs in the union process, the cross-sectional area selected for that member should be the maximum one.
5. Repeat steps 1 through 4 until the design converges. The converged design will satisfy both stress and displacement constraints.

Despite its relative simplicity, and even though it does not incorporate an explicit minimum-weight condition, the MFUD method can yield solutions comparable to those obtained by nonlinear optimization techniques (for example, see figure). Even if one still prefers a full optimization, the MFUD method could be used to generate initial designs for subsequent optimization iterations, thereby alleviating some of the computational burden of optimization.

This work was done by Laszlo Berke and Dale Hopkins of **Lewis Research Center**, *Surya Patnaik of Ohio Aerospace Institute, and Atef Gendy of the National Research Council. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category,* ***or circle no. 109*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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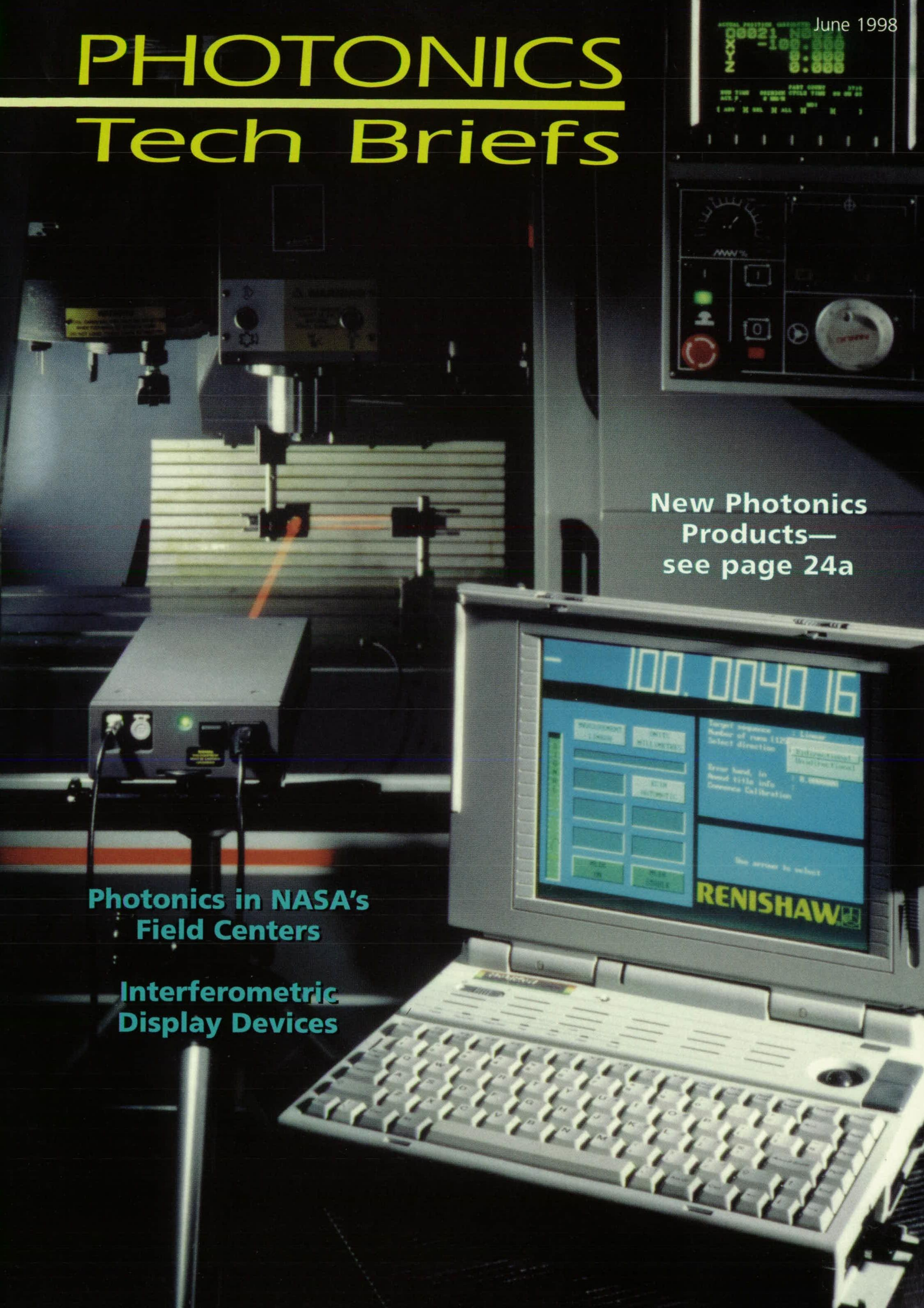
June 1998

PHOTONICS Tech Briefs



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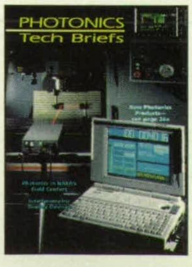
CONTENTS

Feature

Photonics Tech Briefs

Departments



Cover Photo courtesy Renishaw Inc., Schaumburg, IL. See page 8a.

NEWS BRIEFS

Notes from Industry and the Federal Laboratories

At a ceremony in San Francisco during the Conference on Lasers and Electro-Optics (CLEO) in May, the award for *Photonics Tech Briefs*' 1997 Product of the Year was presented to **VLSI Vision Limited** of Edinburgh, Scotland, and San Jose, CA, for the VV6405 single-chip NTSC color camera. Using VLSI's complementary metal-oxide semiconductor (CMOS) technology, the device delivers color video with just a single external crystal and single-rail 5-V power supply. It combines on a single standard CMOS chip a quarter-inch ColorMOS™ photoplane, video timing controller, 8-bit A/D video converter, 300-MIPS color DSP engine, 5 video line memories, auto exposure control and color balance, and NTSC composite video encoder. The chip draws about 100 mA at 5 V, which VLSI says puts its power consumption at about 20 to 30 percent of that of CCDs.

VLSI Vision offers a wide selection of standard CMOS imaging products from core silicon to complete cased cameras with software drivers. Products range from low-resolution monochrome cameras for applications in markets such as toys and security, to high-resolution color sensors designed for the digital still camera market.

Each of the contending products had been a Product of the Month in 1997, chosen by *Photonics Tech Briefs*' editors for outstanding technical merit and practical value to the magazine's engineering and management readers. They were: the **Hewlett-Packard** LSC2500 distributed feedback laser diode; the **Spiricon** LBA-300PC laser beam analyzer; the **New Wave Research** EzLaze™ laser micromachining system; and the **Lambda Physik** NovaLine 100 excimer laser.

Uniphase Corp. of San Jose, CA, announced in April that it had signed a letter of intent with **Royal Philips Electronics** of the Netherlands, to acquire Philips Optoelectronics B.V. of Eindhoven in that country. Philips Optoelectronics manufactures semiconductor laser products for telecommunications, CATV, multimedia, and other markets, including products used in dense wavelength division multiplexing. With approximately 300 employees, the unit will continue to operate in Eindhoven. In addition, a new 60,000-sq.-ft. semiconductor fabrication facility under construction in Eindhoven would be leased to Uniphase. The tangible and intangible assets of Philips Optoelectronics, including approximately 70 U.S. and European patents, are included in the transaction.

Uniphase currently provides the majority of the world's volume of 980-nm semiconductor laser pumps and lithium niobate modulators, and the company is establishing production of fiber Bragg gratings. The Philips Optoelectronics portfolio includes 1550-nm, 1310-nm, and 1480-nm lasers, electro-absorption modulators, semiconductor optical amplifiers, and receivers. Combining the products of the two, Uniphase will be able to provide all of the component categories required by high-capacity fiber optic networks.

Uniphase Corp. is located at 163 Baypointe Pkwy., San Jose, CA 95134; (408) 434-1800; (800) 644-8674; fax: (408) 433-3838.

Photometrics Ltd. of Tucson, AZ, and **Roper Industries Inc.** of Bogart, GA, have signed a definitive purchase agreement whereby Roper will acquire Photometrics' outstanding stock. With approximately 2000 employees, Roper is an international manufacturer of fluid-handling, industrial control, and analytical instrumentation products. Photometrics, a manufacturer of scientific digital imaging equipment, joins Roper's analytical instrumentation products group, which includes **Gatan**, **Princeton Instruments**, **Acton Research Corp.**, **USON**, and **ISL**.

Photometrics is located at 3440 East Britannia Drive, Tucson, AZ 85706; (520) 889-3933; fax: (520) 573-1944.

GE Plastics has opened a new Optical Media Development Center (OMDC) in its Pittsfield, MA, Plastics Polymer Processing Development Center. At the OMDC, GE's customers can participate in the development of manufacturing technologies that are expected to enhance productivity and bring new formats to market faster. According to John O'Sullivan, OMDC's program leader, "We expect the OMDC to help our customers become more productive in their use of ultra-clean LEXAN® resins, and help them meet the requirements of new optical media formats, such as magneto-optical, DVDs, and CD-R."

The OMDC houses the latest optical media manufacturing equipment to simulate the environment of GE Plastics' customers. Companies participating include **Steag Hamatech GmbH**, **Sumitomo Heavy Industries Ltd.**, **CD Associates**, **First Light Technology Inc.**, and **Arburg International**.

GE Plastics is located at 1 Plastics Drive, Pittsfield, MA 01201; (413) 448-4690.

Photonics Shines in NASA's Field Centers

An overview of the Centers' leadership role in optics, lasers, remote sensing, and other photonics disciplines: Final part of three.

At Stennis Space Center, NASA's lead center for commercial remote sensing programs, a demonstration project involving Vexcel Corp. and Shell E&P Technology Co. investigated the potential of LightSAR technology for oil exploration surveys over arid areas frequently covered with thin layers of alluvium. The picture above compares SIR-C space shuttle imaging radar (left), prototypical of LightSAR, with Landsat Thematic Mapper imagery for an area in Jordan where Shell found oil reserves. At left, Kennedy Space Center's optical broadcasting wind indicator measures speed and direction remotely.

NASA programs generate a great wealth of advanced technology, and the agency, through its technology transfer programs, employs a variety of mechanisms to stimulate such transfer to the commercial sector of the economy. Probably the most important linkage is the group of ten NASA field centers located across the country. Many of them have significant work going on in the disciplines of photonics: lasers, optics, fiber optics, electro-optics, video and imaging, design and fabrication, and related areas. Two previous installments (February and April 1998) have dealt with such work in NASA's Jet Propulsion Laboratory, Marshall Space Flight Center, Goddard Space Flight Center, Ames Research Center, Langley Research Center, Lewis Research Center, and Johnson Space Flight Center. The series concludes with examinations of such programs at Kennedy Space Center, Stennis Space Center, and Dryden Flight Research Center.

KENNEDY SPACE CENTER

The Kennedy Space Center reached a major milestone with the start of the Orbital Flight Test Program and the launch of the first space shuttle in 1981. Today, more than 80 shuttle missions later, Kennedy is the locale for shuttle integration and rollout, payload processing, prelaunch checkout, launch, and recovery. These tasks drive the work in the Center's laboratories.

The Space Shuttle Columbia, which went into orbit last year, contained a typical group of instruments to gather data about the vehicle and its environment. The Shuttle Infrared Leeside Temperature Sensing experiment will obtain high-resolution infrared imagery of the upper surface of the orbiter fuselage and left wing during atmospheric entry. The accumulated data will be used to redesign the orbiter's thermal protection system. The Shuttle Upper Atmosphere Mass Spectrometer will deliver measurements of free-stream density during atmospheric entry. When combined with acceleration measurements from the companion high-resolution accelerometer package experiment, the measurements will allow calculation of orbiter aerodynamic coefficients in a flow regime previously inaccessible to experimental and analytic techniques.

The Columbia will also test a laser imaging system for Space Wing Range Safety officials. Currently, these officials monitor a vehicle's position using optical tracking methods that can be impaired by vehicle engine plume, low-level clouds, and fog. Illuminating a portion of the launch vehicle with a noninvasive laser beam is expected to yield clear and defined images of the vehicle even with low visibility.

An example of commercially exploitable technology coming out of Kennedy's operations is the optical broadcasting wind indicator, recently transferred to Atlas Technology Corp. of Boca Raton, FL. The device broadcasts measured wind speeds and direction information via optical flashes from a high-intensity strobe light colocated with the wind sensors.

STENNIS SPACE CENTER

Stennis Space Center is home to the testing of large rocket propulsion systems for the space shuttle and future generations of launch vehicles. It is NASA's lead center for rocket propulsion testing and for commercial remote sensing.

The goal of NASA's Commercial Remote Sensing Program is to enhance U.S. competitiveness through the use of remote sensing, Geographic Information Systems, and related technologies. The CRSP office at Stennis administers several partnership programs designed to transfer NASA's technology and expertise into the commercial sector. Among them is LightSAR, a proposed lightweight, low-cost, space-based

> **"NASA has traditionally measured its progress in terms of technical performance, cost and schedule. Now, in the post-Cold War era there is another measure: contribution of technology to national economic security."**
>
> —NASA Commercial Technology: Agenda for Change (1994)

synthetic aperture radar for commercial and science applications. Four industry-led teams have assessed potential markets and partnering arrangements for LightSAR implementation. The prime contractors for the design definition phase of LightSAR are: DBA Systems Inc. and CTA Space Systems; Lockheed Martin Astronautics; Research & Development Laboratories; and Vexcel Corp.

Stennis is the avenue between NASA's Small Satellite Technology Program and the private sector for encouraging and executing remote sensing applications. Projects include preserving the Central American tropical rain forest, studying sea-surface temperatures to determine conditions for red-tide outbreak, analyzing plant stress, and monitoring cultural and historical archaeological sites.

Remote sensing and Geographic Information System programs are appraised at Stennis, determining their economic benefit, and how best to transfer such approaches to the private sector. A recently formed partnership between Stennis, the University of New Mexico, Jet Propulsion Laboratory, and User Systems Inc., will analyze the more than 18 trillion pieces of information gathered from NASA's shuttle-based synthetic aperture radar for NASA in return for being allowed to find commercial uses for the data.

DRYDEN FLIGHT RESEARCH CENTER

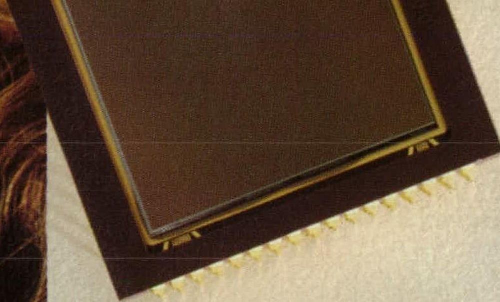
Dryden Flight Research Center's primary study tools are research aircraft, but ground-based facilities also have a key role in the Center's mission as NASA's Center of Excellence for atmospheric flight operations. These include a high-temperature and loads calibration laboratory to test complete aircraft and structural components under the combined effects of loads and heat and a highly developed flight instrumentation capability.

Dryden has cooperated with other NASA centers in the development and evaluation of photonics technology. Dryden's F-18 was the vehicle for the testing of the suite of Lewis-developed fiber optic sensors in the Fiber Optic Control System Integration project.

Sensors play a major part in Dryden-led research. A recent thrust was in flight-qualifiable sensors for inlet air mass flux to improve control of conventional aeroengine gas turbine power plants and variable-geometry, mixed-compression inlets of advanced flight vehicles. Optical techniques are advantageous for inlet measurements, particularly in compressible flows, because they do not disturb the flowfield downstream of the measurement location. Under a Dryden-monitored SBIR contract, Physical Sciences Inc. of Andover, MA, developed an optical air mass flux sensor. On a full-scale Pratt & Whitney F-100 engine in a Dryden ground test, mass flux measurements with an accuracy of 1 or 2 percent over the full range of engine operating conditions were achieved.

A key Dryden endeavor is the Environmental Research Aircraft and Sensor Technology program, or ERAST. It is an effort by a NASA-industry alliance to develop aeronautical technologies to support a family of unpiloted aircraft to carry out scientific and environmental missions at heights of up to 100,000 feet and durations of several days or more. Dryden is the lead NASA center in the seven-year evaluation program. ERAST is sponsoring the development of the Suntracking Sunphotometer to support the Tropospheric Aerosol Radiative Forcing Observational Experiment on the eastern seaboard.

On the cover: *The HeNe laser interferometer from Renishaw Inc., Schaumburg, IL, is shown being used to automatically calibrate and compensate for machine tool positioning errors. Photo courtesy Renishaw.*



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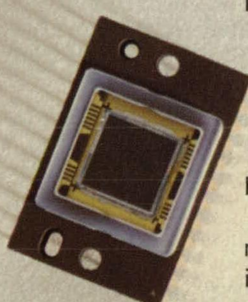

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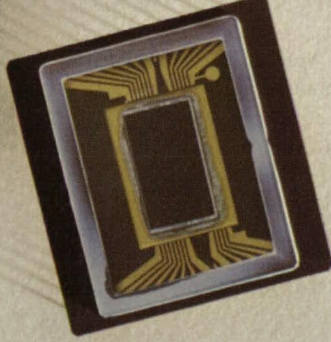

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Micromachined Interferometric Optoelectronic Display Devices

Miniature Fabry-Perot interferometers would be used as modulators to mix colors.

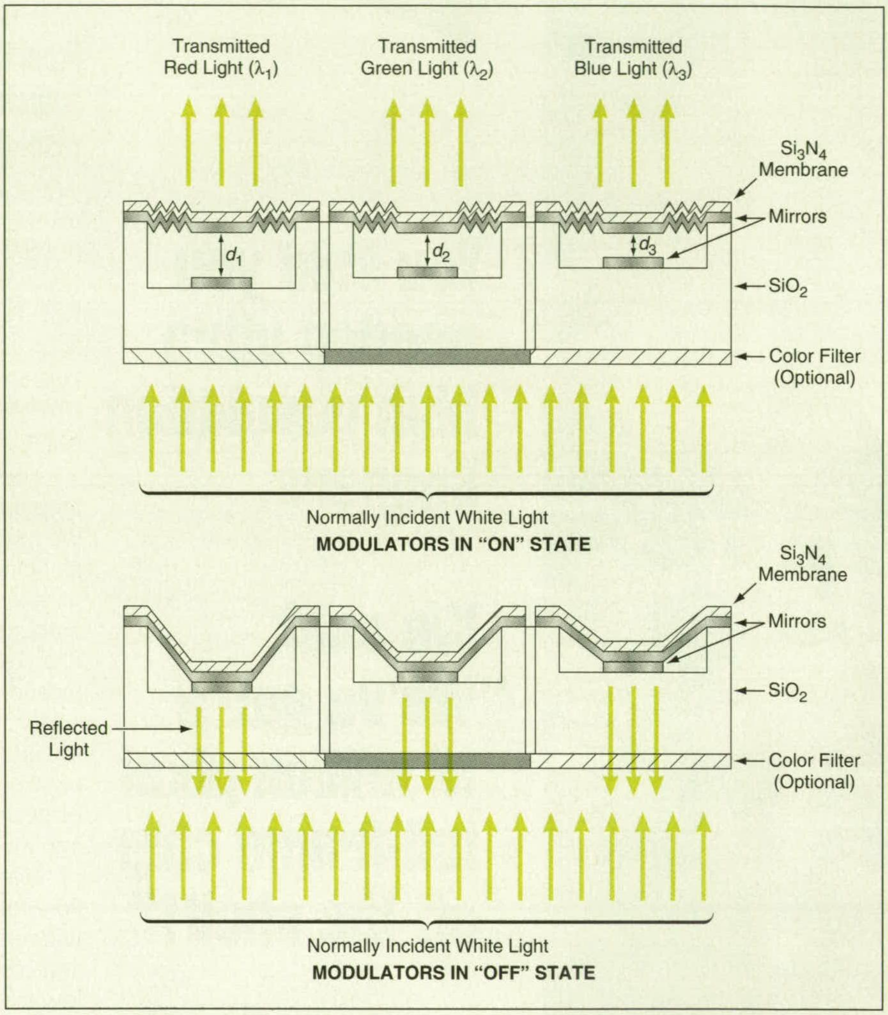
NASA's Jet Propulsion Laboratory, Pasadena, California

Devices containing planar arrays of micromachined, electrostatically adjustable Fabry-Perot interferometers are undergoing development. These devices could be designed, for example, as color high-definition television displays, as larger flat-panel displays for indoor and outdoor entertainment and advertising, as filter arrays for spectroscopy, and as modulator arrays for optical computing and switching. In comparison with state-of-the-art flat-panel display devices based on liquid crystals, plasmas, and electroluminescence, the present devices offer potential advantages of high speed, insensitivity to changes in temperature, low power consumption, wide viewing angle, scalability, light weight, and long life.

A related concept of using two-stage, micromachined, electrostatically adjustable Fabry-Perot interferometers as rapidly tunable color filters and shutters was presented in "Micromachined Opto / Electro / Mechanical Systems" (NPO-19467), *NASA Tech Briefs*, Vol. 21, No. 3 (March 1997), page 50, and "Micromachined Tunable Optical Interference Filters" (NPO-19456), *NASA Tech Briefs*, Vol. 21, No. 3 (March 1997), page 111. The devices being developed according to the present concept are based on the same physical principles but differ in significant details of design and modes of operation.

In a three-color television display device according to the present concept, each pixel would contain three micromachined, electrostatically adjustable Fabry-Perot interferometers, each serving as a modulator for light of one of three wavelengths (see figure). Each micromachined interferometer would contain two parallel, flat, partially transparent mirrors — one on a springy silicon nitride membrane and the other on a stationary glass substrate. The mirrors and the gap between them would constitute an optical cavity with resonant transmission peaks at wavelengths equal to integer submultiples of twice the size of the gap; that is, the interferometer would transmit most of the light at these wavelengths and reflect most of the light at other wavelengths.

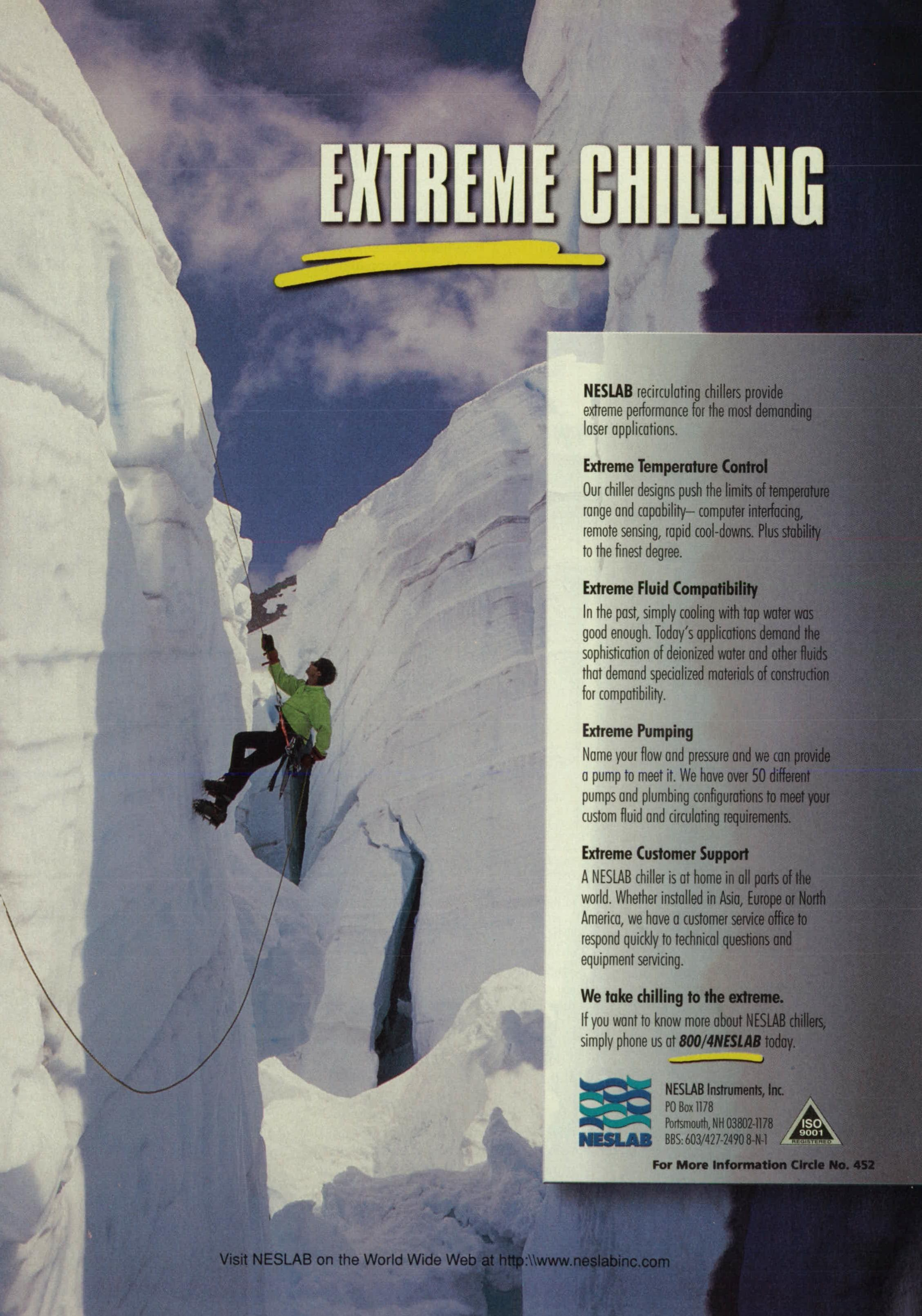
The nominal size of the gap in each micromachined interferometer would be selected so that its resonant wavelength in the visible part of the spectrum was that of the desired color. The display panel would be illuminated with white light from its back side (the lower side in the figure). Optionally, color filters could be formed on the back side registered with the corresponding interferometers to provide additional selectivity for greater purity of the colors.



Each of Three Micromachined Interferometers in a pixel would either transmit light at a resonant wavelength λi when relaxed at gap d_i, or else would not transmit when its mirrors were pulled together by voltage applied to electrostatic-deflection electrodes.

When voltage was not applied to the electrostatic-deflection electrodes, the springy silicon nitride membrane in each interferometer would maintain the nominal gap and therefore light of the nominal wavelength would pass through to the front (top in the figure) side, where it would be seen. When voltage was applied to the electrostatic-deflection electrodes of a given color interferometer in a given pixel, the spring force would be overcome and the two mirrors drawn together; this would eliminate the resonant gap, causing the two mirrors to act as ordinary mirrors so that light would not pass through to the front. The net effect would be that each interferometer would act as a light valve or modulator for its assigned color. Thus, by opening each light valve for a specified fraction of each image-repetition cycle, one could mix specified proportions of each color. Since the viewer's eye could not spatially resolve the individual interferometers or temporally resolve the individual flashes of light, the viewer would get the impression of a desired composite color emanating from the pixel.

This work was done by Tony K. T. Tang, Linda M. Miller, Michael H. Hecht, and Judith A. Podosek of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components & Circuits category,* ***or circle no. 130*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). NPO-19527*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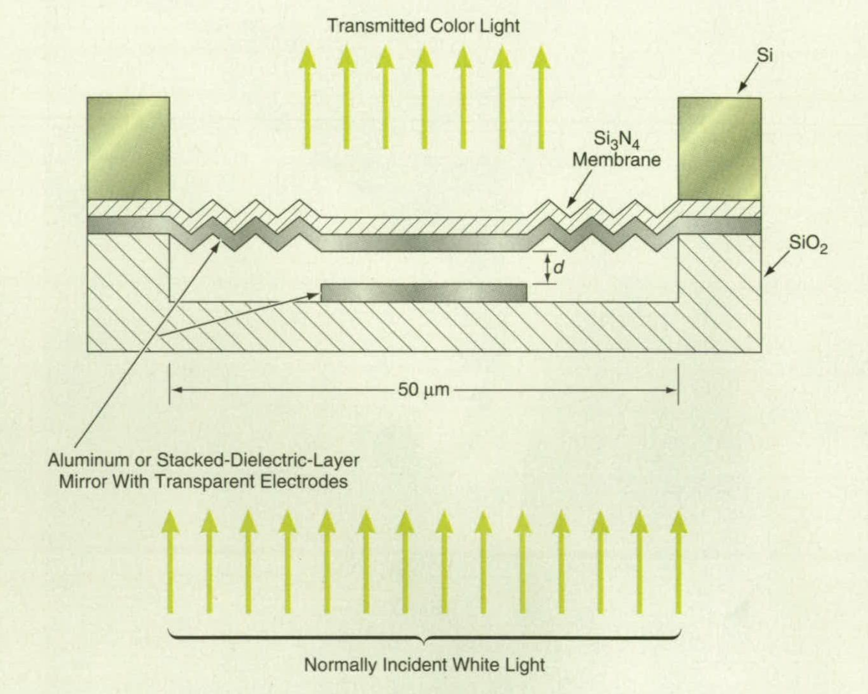
Variable-Wavelength Micromachined Fabry-Perot Interferometers

Displayed colors would be varied at will.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure schematically shows a micromachined Fabry-Perot interferometer that, when fully developed, would be part of a two-dimensional array of such interferometers in a flat-panel display device. The interferometers, arrays, and display devices according to this concept would be similar to those described in the preceding article, "Micromachined Interferometric Optoelectronic Display Devices" (NPO-19527). The basic principles of design and operation are the same, but there would be differences in some of the details.



This **Micromachined Fabry-Perot Interferometer** would pass light at a resonant wavelength equal to $2nd/m$, where n is the index of refraction of the medium between the mirrors, d is the gap width shown in the figure, and m is an integer that denotes the order of interference. The voltage applied to the transparent electrodes would be varied to vary d and thus the transmitted color.

The major difference in design would be that a device of this type would contain only one micromachined Fabry-Perot interferometer per pixel instead of three as in the devices of the preceding article. The major difference in operation is that instead of using each micromachined Fabry-Perot interferometer as an on/off modulator for light of a preset wavelength, one would use each such interferometer as a tunable band-pass filter and "off" switch: the voltage applied to the electrostatic-deflection electrodes of the interferometer in each pixel could be varied as a function of time to make light of a chosen wavelength pass through at a given time, or the voltage could be increased to a level sufficient to draw the interferometer mirrors together so that no light would pass through. That is, by controlling the voltage applied to each pixel, one could either make it appear to glow in a chosen color or else go dark.

The feasibility of this concept was demonstrated in an experiment on a prototype. The distance between the mirrors was varied, causing the transmitted color to vary between red and blue.

This work was done by Tony K. T. Tang, Linda M. Miller, and Judith A. Podosek of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components & Circuits category,* ***or circle no. 131*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-19528

Enhancements to Fiber Optic Bragg Grating Sensors and Demodulation Systems

The sensors and sensor signal readout are improved.

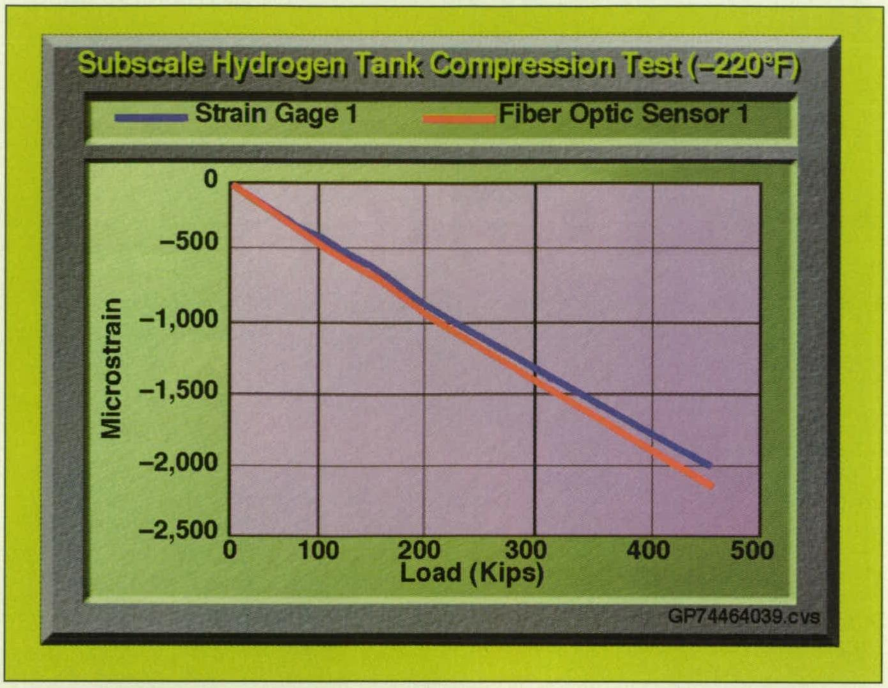
The Boeing Company, St. Louis, Missouri

The Boeing Company has developed and patented certain enhancements to commercially available Bragg grating sensors and demodulation systems. These patents (Nos. 4,471,659, 4,668,093, 5,380,995, 5,563,967, and 5,627,927) are available for license. Knowhow related to these patents is available through laboratory and engineering services offered by Boeing.

The enhancements cover two areas, the sensors themselves and sensor signal readout. The double-core Bragg grating fiber optic sensor consists of a fiber optic designed to transmit different wavelengths of light. Bragg gratings at two wavelengths are written at the same location on the fiber optic. The response from these gratings can be used to simultaneously determine both the strain and temperature on the fiber optic. The multiple overlapping grating method further enhances the separation of variables by allowing separation of x-axis strain, y-axis strain, z-axis strain, and temperature from one sensing location.

High-speed sensor signal readout is improved via an additional pending patent that allows efficient integration of multiple strings of sensors and the use of less expensive sources at the same time. This technique could readily be adapted to telecom applications to reduce cost.

Bragg gratings represent a relatively simple, compact, and low-cost approach to measuring strain or temperature in carbon and glass composite embedding applications. The simplicity arises because there is no need to measure optical phase, and hence no need for a coherent light source. Light demodulation instruments are difficult and costly to manufacture; thus the use of Bragg gratings results in a significant cost savings. Since these gratings can be written at different wavelengths, many individual sensors can be wavelength-division-multiplexed and integrated onto a single fiber optic strand.



Subscale Hydrogen Tank Compression Test (-220°F)

Fiber optic sensors can be embedded into the composite without degrading the mechanical performance of the part.

Bragg gratings provide significant and important enhancements to fiber optic technology, enabling the integration of the grating filters, reflectors, tunable lasers, couplers, and sensing elements directly in the waveguiding core of the fiber optic. The Federal Highway Administration has attached Bragg grating sensors to reinforcing rods and to concrete in numerous roads and bridges.

Bragg gratings may be fabricated on most commercially available fibers. The gratings' reflection and transmission response can also be custom-designed to specifications.

These Bragg grating enhancements are now available for license for use with commercially available Bragg grating and demodulation systems. Bragg grating enhancements are continually being researched and developed further by the Boeing Company, drawing upon the successful implementation of this technology on the Structural Health Monitoring System for the composite Clipper Graham® LH_2 cryotank (see graph) built for NASA.

The Boeing Company *is currently developing business relationships with companies interested in applying Boeing technologies to their products. If actively interested, please contact Dennis Donahue, Marketing Manager, Licensing; MC 306-1285, PO Box 516, St. Louis, MO 63166; (314) 234-7093; fax (314) 232-4313; http://www.boeing.com/assocproducts/mdip/.*

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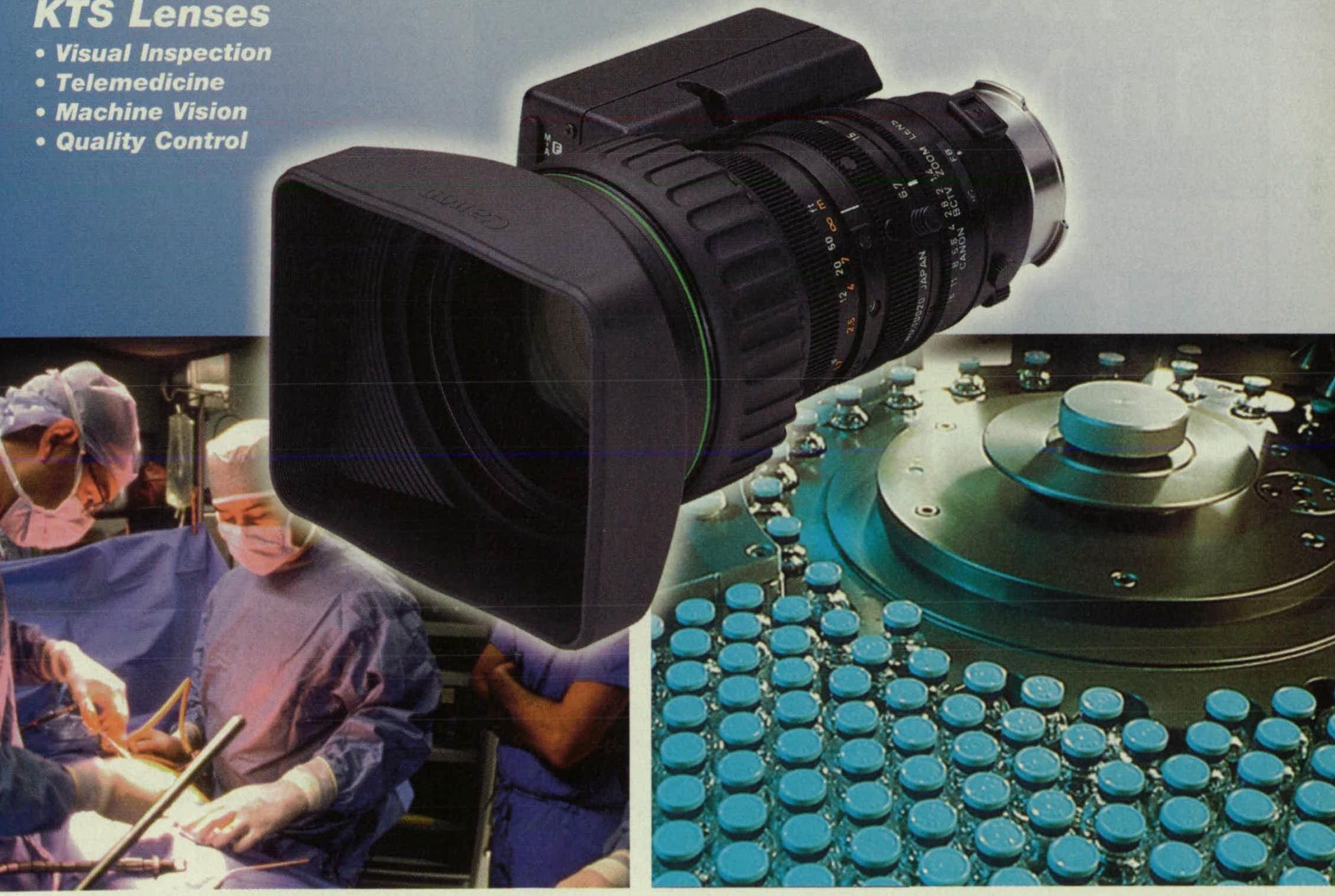

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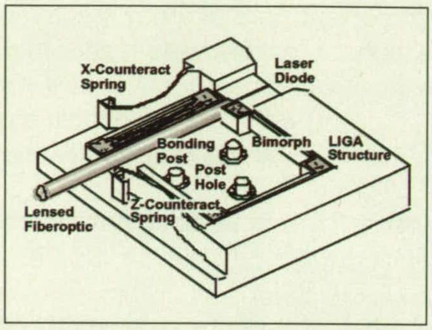
Active Fiber Optic Microelectromechanical Systems Aligner

The cost per aligned fiber optic is significantly less than the device to be pigtailed.

The Boeing Company, St. Louis, Missouri

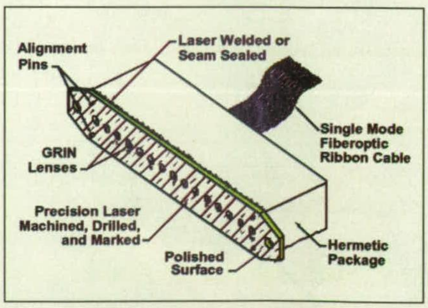
As currently practiced, packaging of individual optoelectronic components accounts for 40-50 percent of product cost. The development of higher-volume, lower-cost optoelectronic manufacturing technologies must take place in order to accelerate the installation of optoelectronics in lower-speed and shorter-distance networks, such as telecommunications, computer, and video applications for both defense and commercial systems.



Schematic of the **Active Fiber-Optic Micro Aligner**. Components of the embedded microactuator include the X- and Y-counteract springs, and the bimorph.

The microelectromechanical systems (MEMS) devices and fabrication and packaging described herein were developed by the Boeing Company to address needs for the coupling of single-mode optical components for military and commercial applications. The company has demonstrated for the first time a fully integrated wafer-level processed active fiber-optic micro aligner (AFMA). These MEMS devices are capable of large force and displacements with submicron accuracy. The technology is covered by three patents (Nos. 5,606,635, 5,602,955, and 5,553,182).

One of the principal reasons more applications of photonic (all-optical) devices and optoelectronics are not seen in the consumer and business marketplace is the lack of reliable cost-effective and easily implemented fiber optic alignment and bonding to discrete optoelectronic and photonics devices. The problem is the need to align optical components and fiber optics with submicron ($<1 \times 10^{-6}$ m) precision in less than 0.1 minute, with the cost per aligned fiber optic significantly less than



Schematic of an **Array of Active Fiber-Optic Micro Aligners**.

the device to be pigtailed. This submicron or nanometer precision is even more critical for the more efficient lensed fiber optics.

MEMS-based actuation during the manufacturing of packaged-fiber optically coupled optoelectronic devices would meet the cost-per-alignment requirements. This AFMA technology can satisfy this need short-term while at the same time solving problems associated with the realization of the all-optical photonic system.

The primary application for active fiber micro-actuators is highly cost-effective in-package alignment and coupling of single-mode fiber optics (single or multiple fibers) to laser diodes in small packages. The process works with lensed or unlensed fibers and is polarization-preserving. Other applications include single-mode fiber optic backplane connectors and a multiple-fiber-optic connector.

The Boeing Company has fully developed fabrication, testing, and packaging methods for the AFMA devices. Currently there are several more active fiber optic components and methods that the company has disclosed to the U.S. Patent and Trademark Office.

The Boeing Company *is currently developing business relationships with companies interested in applying Boeing Co. technologies to their products. If actively interested, please contact Dennis Donahue, Marketing Manager, Licensing; MC 306-1285, PO Box 516, St. Louis, MO 63166; (314) 234-7093; fax: (314) 232-4313; http://www.boeing.com/assocproducts/mdip/.*

Making Single-Crystal Fibers in a Laser-Heated Floating Zone

Process parameters can be controlled to obtain high-quality single-crystal fibers.

Lewis Research Center, Cleveland, Ohio

Figure 1 shows an apparatus for growing a single-crystal fiber by solidification from a floating zone of laser-heated molten material on the tip of a feed rod. The apparatus can be used to produce single-crystal fibers of various highly pure ceramic and metal compo-

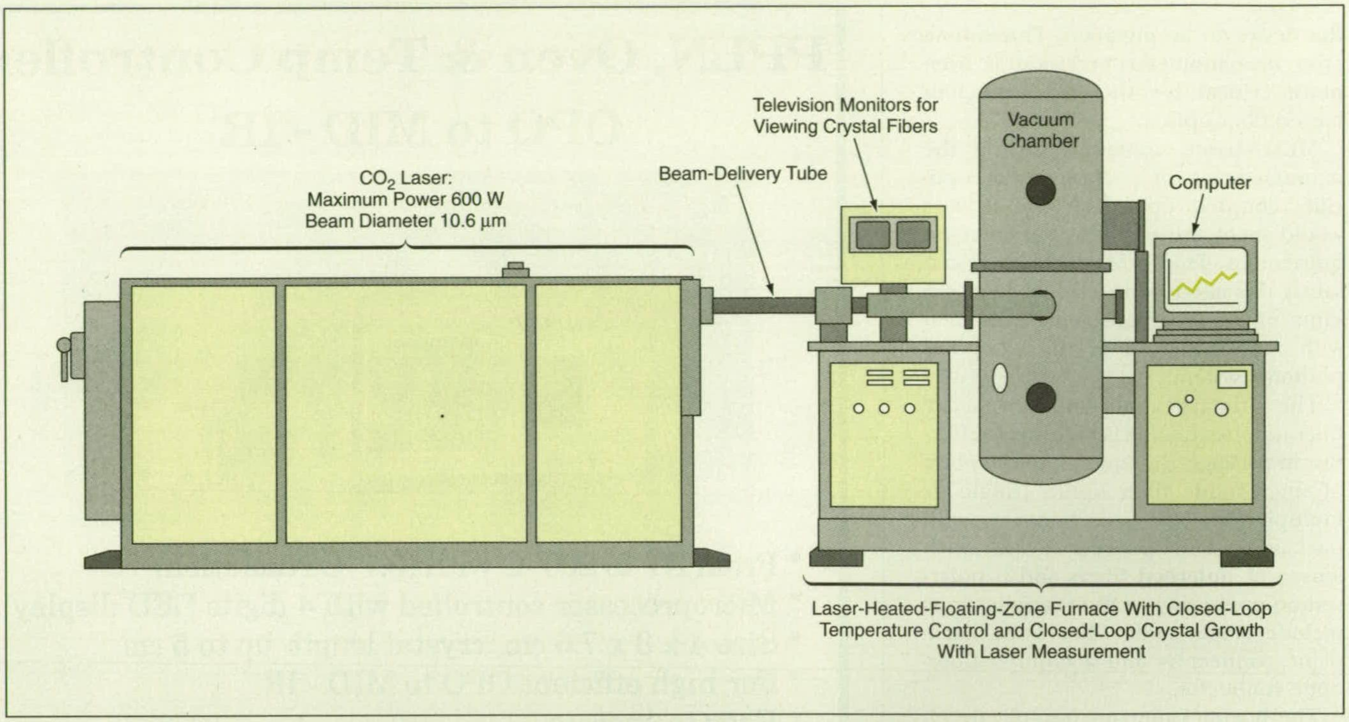


Figure 1. In the **Laser-Heated Floating-Zone Apparatus**, single-crystal fibers can be grown with controlled diameters and specified crystalline orientations.

sitions, controlled crystal orientations, and small, uniform diameters. Such fibers are needed for experimental research on fiber reinforcements for metal-matrix/fiber and intermetallic-matrix/fiber composite materials. Fiber compositions that have been produced thus far include sapphire (Al_2O_3) with and without ternary additions, ZrO_2, and yttrium aluminum garnet (YAG). Typical fiber diameters have ranged from 100 to 250 µm.

Preparation of a feed rod begins with mixing of metallic or ceramic powders with an organic binder. The powders are formulated with a modified stoichiometric composition; that is, the composition is chosen to obtain the desired fiber crystal composition, taking account of anticipated losses of various constituents through differential vaporization from the melt. The mixture of powders and organic binder is extruded to produce the feed rod. The organic binder is typically a commercial water-soluble cellulose ether product formulated to obtain the desired extrusion properties and to vaporize during subsequent laser heating, leaving behind little or no residue.

The feed rod is mounted vertically on a vertical-translation mechanism inside the vacuum chamber. A seed crystal (which could be a piece of previously grown fiber) is placed in the desired orientation by use of x-ray diffraction for measurement and a goniometer for adjustment. The oriented seed crystal is mounted in the desired orientation on the tip of a pull rod that is collinear with the feed rod and is connected to another, independently controllable vertical-translation mechanism inside the vacuum chamber.

The laser beam is split into two beams aimed at the floating-zone melt location from opposite sides. The tip of the feed rod and the seed crystal on the tip of the pull rod are slowly brought toward each other and into the laser-heated floating zone, causing them to begin to melt (see Figure 2). Eventually, the molten tips touch and wet each other. Once a stable molten zone with a relatively uniform temperature profile has been established, growth of a single-crystal fiber can begin.

To effect this growth, the feed rod is translated toward the laser-heated zone at one speed while the pull rod is translated away from the laser-heated zone at a different speed. The ratio between the speeds is chosen to obtain the desired change from the diameter of the feed rod to the diameter of the fiber. Ordinarily, one seeks to produce a fiber narrower than the feed rod, so that the pull rod must be translated

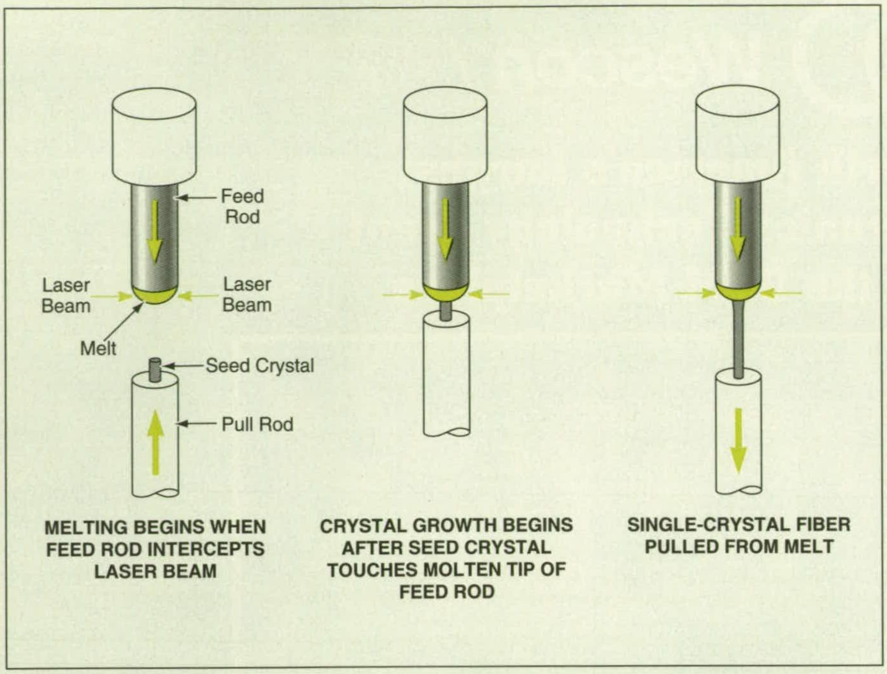


Figure 2. The **Seed Crystal and Feed Rod** are brought together in the laser-heated zone. Once a stable melt has been established, the feed rod is slowly fed into the laser-heated zone while the pull rod is withdrawn to pull out the growing fiber.

more rapidly. The translation can be either downward as in Figure 2, or else upward.

A technique called "melt modulation" is used to maintain stability and symmetry in the molten zone. Melt modulation is effected by optomechanically scanning the opposing laser beams back and forth across the feed-rod/fiber axis to obtain more nearly even heating. Melt modulation gives rise to small vibrations that help to stabilize the molten zone. The vibrations also increase thermal agitation and mixing, thereby helping to make the temperature more nearly uniform throughout the melt. The vibrations also help to shake bubbles out of the melt; without the vibrations, small bubbles tend to coalesce into one large bubble in the molten zone, with consequent disruption of crystal growth. The frequency of vibration can be adjusted to avoid mechanical resonances and minimize vibration of the growing crystal. Typically, the optimum frequency lies between 30 and 50 Hz.

This work was done by Frank Ritzert and Leonard Westfall of **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 132*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16539.

Room-Temperature External-Cavity Diode Lasers at 2.0 µm

These are the first commercially available room-temperature broadly tunable diode lasers with output wavelengths in the 2.0-µm range.

Focused Research Inc. and New Focus Inc., Santa Clara, California

External-cavity diode lasers (ECDLs) have been commercially available for several years. Since their introduction, they have found applications ranging from telecommunications to atomic spectroscopy. These lasers provide a combination of extremely narrow linewidth, broad tunability, and ease of use, making them some of the most versatile lasers available. Until recently, the accessible wavelengths have been limited to the 0.6-1.6-µm region where commercial laser diodes are available. Development conducted by Focused Research, a research subsidiary of New Focus, and Sarnoff Corporation, with support from NASA Goddard Space Flight Center, has extended this range, resulting in the commercialization of the first external-cavity diode laser operating beyond 2.0 µm.

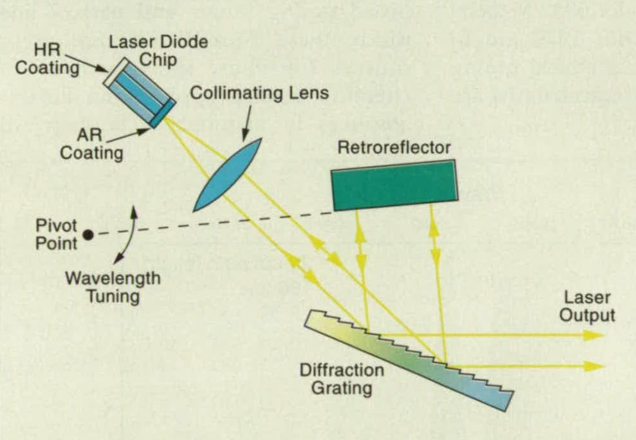


Figure 1. Schematic of a **Modified Littman-Metcalf Laser Cavity**.

To develop this technology, researchers designed and fabricated a new strained-layer InGaAs/InP quantum-well ridge-waveguide semiconductor laser. Tensile strain was then added in the barrier region to extend the operating wavelength beyond 2.0 µm. To suppress laser oscillation between the facets of the diode, an antireflection coating was deposited onto the output facet. The quality of the antireflection coating is critical to achieving single-mode operation with narrow linewidths and wide tuning ranges, as oscillations between the facets will interfere with the effectiveness of the external cavity.

The laser is then placed in an external cavity with a grating in a Littman-Metcalf grazing incidence configuration, as illustrated in Figure 1, The grating serves as the wavelength-selective output coupler. The narrow linewidth is a result of the highly dispersive nature of the grating, which forces the laser to oscillate in a single longitudinal mode at any given setting. Adjusting the angle of the feedback mirror (or retroreflector) with respect to the grating tunes the output wavelength. There are two methods of doing this: a DC motor provides rapid (>10 nm/s) coarse tuning over the entire tuning range of greater than 70 nm. Fine wavelength adjustment is achieved with a

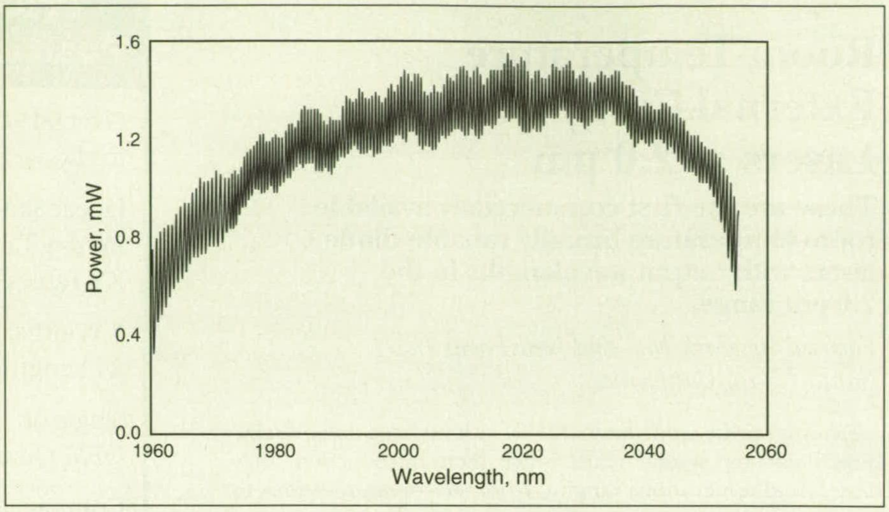


Figure 2. **Typical Tuning Curve** of a Model 6332 Velocity 2-μm laser.

stack of piezoelectric crystals. This piezo stack provides the user with the ability to modulate the output wavelength with frequencies as high as 2 kHz. When faster modulation is required, a direct connection to the diode itself is provided for current modulation. The total tuning range of the piezo stack is approximately 20 GHz (about 0.27 nm). The new product (Model 6332 Velocity Laser) tunes from about 1970 nm to 2040 (see Figure 2 for a typical tuning curve). Nearby custom wavelengths are also available.

field applications. Until the development of these lasers, researchers had to use cryogenic color-center or lead-salt lasers or complicated nonlinear schemes. These systems require much more care and time than the new lasers, and are generally used only in research labs.

With their combination of simplicity, broad tuning range, and narrow linewidth, these 2-μm ECDLs are useful sources for many spectroscopic and chemical sensing applications. Further advances in materials technology will continue to fuel development in laser diodes. As longer-wavelength materials become available, New Focus anticipates their rapid integration into external-cavity tunable systems.

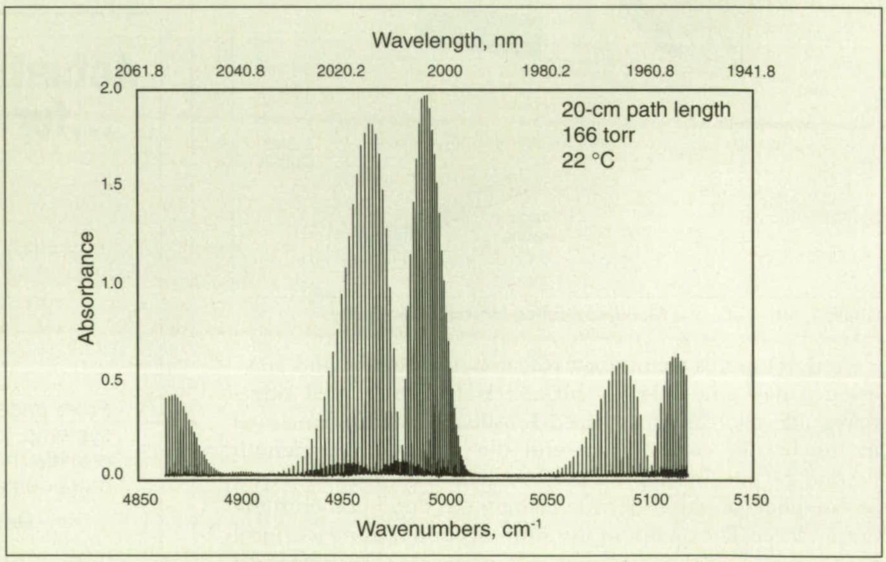


Figure 3. **Survey Spectra** of CO_2 taken with a 2-μm Velocity laser. Data courtesy of Stanford University's High-Temperature Gasdynamics Laboratory.

The 2.0-μm wavelength region is especially useful for spectroscopy of molecular species such as CO_2, H_2O, N_2O, and NH_3, for combustion diagnostics and environmental monitoring, and HBr for *in-situ* gas-phase substrate etching for the semiconductor industry. Figure 3 shows data from a survey spectrum of CO_2 taken with the Model 6332 Velocity laser. The laser itself is compact and uses wall-plug power, making it useful for

This work was done by Dr. Tim Day, Dr. I-Fan Wu, Dr. Bill Chapman, and Greg Feller at Focused Research, Inc., a subsidiary of **New Focus Inc.**, *Santa Clara, CA. For more information, please call New Focus at (408) 980-8088.*

NEW LITERATURE

Fiber Optic Video Link

Math Associates, Hauppauge, NY, is offering a specification sheet on its new Beamer fiber optic video link. The company calls Beamer a complete high-quality cost-effective transmission system designed to transmit color or black-and-white video signals across distances from a few feet to more than a mile. Consisting of a transmitter, receiver, and two power supplies, Beamer transmits over standard 62.5-micron multimode fiber optic cable. It is compatible with all standard analog video formats, including NTSC, PAL, and SECAM, and operates with industry-standard ST-type connectors. Specifications provided include signal-to-noise ratio, differential gain and phase, optical loss budget, and operating temperature.

For More Information Circle No. 767

Lightwave Test and Measurement Guide

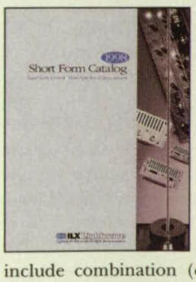
EXFO E. O. Engineering, Vanier, P.Q., Canada, offers its "1998 Lightwave Test and Measurement Reference Guide," showcasing its most recent developments in fiber optic test and measurement technology. Among new products outlined in the catalog are the dense WDM testing line, which includes a PDL analyzer and tunable lasers, and new modules for the FTB-300 universal test system. The guide has more than 240 pages of information for fiber optic specialists, enhanced with diagrams, tables, and graphs. Also included is equipment for performing fiber geometry analysis and spectral attenuation measurements for cable and fiber manufacturers.

For More Information Circle No. 770

Coating Technology Innovation

ZC&R Inc., Carson, CA, has published an 8-page full-color catalog titled "Coating Technology Innovation." The document provides specifications on the company's extensive line of standard off-the-shelf and custom coatings. Included are reflectance and transmittance curves on antireflection, metal, transparent conductive, and ultrahigh-power laser coatings, infrared filters, BlackLite and color dichroic filters, thin-film polarizers, color and heat control filters, and beamsplitters.

For More Information Circle No. 773



Laboratory Benchtop Instrumentation

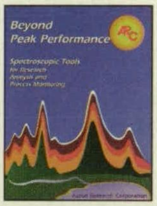
The new "1998 Short Form Catalog" from ILX Lightwave, Bozeman, MT, contains information on the company's instrumentation for laser diode control and fiber optic test and measurement. New products include combination (current and TEC) modules for the LDC-3900 laser diode controllers; the LDM-4984RF laser diode mount for telecom laser diodes; WDM DFB and external-cavity laser modules for the 7900 modular fiber optic source system, and the 8012/24 single- and dual-output low-cost fiber optic sources; and more.

For More Information Circle No. 776

Optics and Parts for Laser Systems

Convergent Energy, Sturbridge, MA, has produced a 48-page catalog of replacement parts for its carbon dioxide and Nd:YAG laser systems. The catalog also includes widely used mirrors; gas discharge, flash, and arc lamps; and beam delivery optics for Nd:glass, YAG, and carbon dioxide lasers. Separate sections of the catalog detail the company's laser offerings, diagnostic and safety equipment, customer support capabilities, and the care and cleaning of optics.

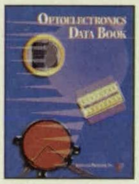
For More Information Circle No. 768



Spectral Data Acquisition Systems

Now available from Acton Research Corp., Acton, MA, is a full-color brochure called "Beyond Peak Performance," detailing spectroscopic tools for research, analysis, and process monitoring. Featured is the new NCL™ high-performance spectral data acquisition system for spectroscopy. Combined with ARC's SpectraSense™ software, it makes real-time data collection, system automation, and chemometric analysis possible for process monitoring and research applications. The brochure gives specifications for SpectraSense software, the NCL electronic interface, and SpectraPro™ monochromators and spectrographs.

For More Information Circle No. 771



Optoelectronics Data Book

Advanced Photonix Inc., Camarillo, CA, has issued a 40-page capabilities brochure and product specification guide called the "Optoelectronics Data Book." The publication provides details of the company's design and engineering, manufacturing, testing, and quality assurance capabilities; a technical section on the theory of operation of photodiodes; a glossary of terms; diagrams of typical operating circuits; and a selection guide. Specifications are given for ultralow-noise, general-purpose, high-speed, UV-enhanced, and blue-enhanced PIN photodiodes; solderable chips; low-noise, general-purpose, and high-speed silicon detector/preamplifiers, and more.

For More Information Circle No. 774

Photonics Surface Preparation Equipment

Ultra Tec Manufacturing Inc., Santa Ana, CA, has prepared a series of specification sheets on its line of precision saws and lapping and polishing machines. Included are the Ultraslice and Microslice saws that provide precision sectioning for a wide range of applications. Microslice 2 provides an annular cutting mode, making it the choice for many users in optical and material science applications. The company says that the Ultrapol 1200 series polishers offer maximum versatility in preparing samples of all shapes and orientations. The UT-1600 Micropositioned Polishing Heads may be oriented in all planes to suit optical, optoelectronic, and fiber-type workpieces.

For More Information Circle No. 777

Spectrophotometer with FO Dip Probe

A recently published brochure from Varian Analytical Instruments, Palo Alto, CA, focuses on the Cary 50 spectrophotometer. The company says its new xenon flashlamp technology offers better efficiency, longer lamp life, and no sample degradation. Full-color diagrams and photographs illustrate the Cary 50's flexibility and range for applications such as scanning, kinetics studies, and concentration measurements. The brochure highlights the instrument accessories, such as the fiber optic dip probe for speedy, precise liquid sampling without cuvettes.

For More Information Circle No. 769

Replacement Optics for CO2 Lasers

A new brochure describing lenses, mirrors, phase retardation reflectors, and other optics for industrial carbon dioxide lasers is available from Laser Research Optics, Providence, RI. The brochure features low-absorption ZnSe positive focusing lenses and molybdenum mirrors, and has descriptions, photographs and technical specifications for each of the many product categories.

For More Information Circle No. 772

NEW PRODUCTS

PRODUCT OF THE MONTH

Optical Linear Encoder

BEI Sensors & Systems Co.'s Encoder Systems Division, Sylmar, CA, introduces its LIE5 Series optical linear encoders, the first product to be developed under a new business alliance with Carl Zeiss Group. Called the most efficient microelectronic technology to result from an extensive research and development effort by the two companies, the LIE5 encoder is a reflective-read device that works in conjunction with a steel measuring scale. BEI says the head employs flip-chip-on-glass optics, which account for its small size as well as its ability to include built-in interpolation circuitry with resolutions as fine as 0.1 μm and output frequency up to 36 MHz. The head's dual scanning arrays allow for continued reading under contamination conditions that the company says would prove fatal to other linear encoders. The package measures only 34 mm × 13.2 mm × 12.4 mm, offering multiple mounting options. The scale features etched graduation marking of a 20-μm pitch with high optical accuracy; custom scale options are available.

For More Information Circle No. 793

IR Camera for Predictive Maintenance

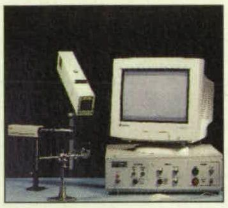
Raytheon, Goleta, CA, makes available ExplorIR, an infrared camera designed for predictive maintenance and condition monitoring applications. Incorporating a 320-×-240-pixel uncooled focal plane array, the camera operates in the 8-to-14-μm range with a sensitivity of 0.15 °C. Measurement accuracy is ±4 percent or ±4 °C, whichever is greater. Weighing 5.5 pounds, the camera has a flip-out 5-in. active-matrix color display, designed to function in high ambient light. The system has two models: the SR features a measurement range of −20 °C to 300 °C, while the ER model enables measurement up to 900 °C.

For More Information Circle No. 794

Laser Power Measurement Systems

The LPMS Series of laser power measurement systems from Labsphere Inc., North Sutton, NH, includes two precision power meters designed to measure the total output power of lasers or highly divergent sources. Integrating-sphere systems are available for measurements, insensitive to polarization and input-beam alignment, over the wavelength region from 300 to 1800 nm. These systems consist of an integrating sphere, detector assembly, and system control, with calibration traceable to the National Institute of Standards and Technology.

For More Information Circle No. 795



Flow Visualization Imaging System

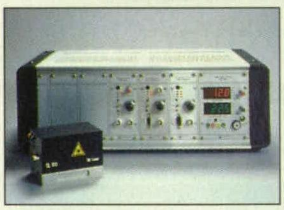
The Saber 2/4™ system from Oxford Lasers Inc., Acton, MA, is a fully integrated particle image velocimetry (PIV) system consisting of the HSI1000 solid-state pulsed laser illuminator, a megapixel cross-correlation camera, digital frame-grabber, Visiflow™ PIV analysis software, and fully configured PC for image capture and analysis. In cross-correlation mode, the imaging system provides the ability to capture two frames with as little as 10 μs of time separation. The fully digital system enables image capture to be externally triggered for precise timing with external events.

For More Information Circle No. 796

Small-Diameter Borescope

Gradient Lens Corp., Rochester, NY, introduces the Super Slim, part of the Hawkeye Precision Borescope line. The instrument is just 2.4 millimeters wide. Because it is based on gradient-index (GRIN) optics, one long straight glass rod takes the place of many tiny lenses that make up the insides of other micro borescopes. Gradient Lens says that Hawkeye borescopes cost about a third to a half of today's conventional instruments. The company says its patented endoGRINS design results in rods that are unique in having negative dispersion, which virtually eliminates aberrations such as color fringing and loss of sharpness.

For More Information Circle No. 797



Single-Mode Tunable Diode Laser

Polytec PI Inc., Auburn, MA, the exclusive U.S. distributor for TUI Laser of Munich, Germany, offers TUI's DL100 tunable grating-stabilized diode laser. With up to 100 mW of power, a linewidth of less than 1 MHz, and a 15-nm tunability for each diode, the DL100 is ideal for spectroscopy, interferometry, and gas analysis, Polytec PI says. A total tuning range of 630-1600 nm is possible with a variety of diodes, and optional frequency doubling and amplification are available.

For More Information Circle No. 798

Optical Wavelength Meters for WDM

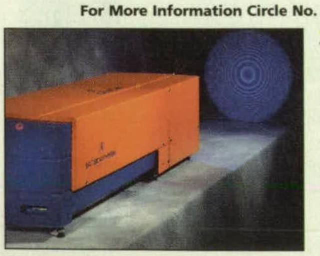
Burleigh Instruments Inc., Fishers, NY, says its new WA-1600 and WA-1100 Wavemeter™ optical wavelength meters are designed specifically for characterization of wavelength division multiplexing components in manufacturing environments. Using Wavemeter's scanning Michelson interferometer-based technology to compare fringe patterns with those of a built-in HeNe laser wavelength standard, the meters achieve absolute wavelength accuracy of ±0.2 ppm. The Wavemeters also measure total optical power, and monitor, as a function of time, changes in wavelength or power of an optical signal.

For More Information Circle No. 799

Thin-Film Thickness Mapping System

The F50 system from Filmetrics Inc., San Diego, CA, is a thin-film thickness mapping system designed for optical coating and semiconductor wafer applications. It automatically measures the thickness of oxides, nitrides, resists, polymers, and other films used in silicon, III-IV, and LCD fabrication. It will measure films between 20 nm and 30 μm thick on substrates up to 8 in. in diameter. In addition, the system models and characterizes a multitude of complex multilayer optoelectronic structures, including vertical-cavity lasers and distributed Bragg reflectors.

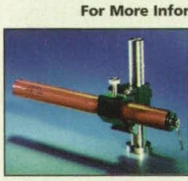
For More Information Circle No. 800



Tunable Laser with Direct UV Output

Lambda Physik Inc., Fort Lauderdale, FL, calls its UV-Star™ the first commercially available, all-solid-state tunable laser with direct output in the ultraviolet. UV-Star consists of a cerium-doped $LiCaAlF_6$ laser pumped by a Lambda Physik StarLine™ 266 frequency-quadrupled Nd:YAG laser. UV-Star can be continuously tuned from 282 to 310 nm. Maximum output power is more than 150 mW with a bandwidth of less than 250 pm. At a repetition rate of up to 1 kHz, output pulse duration is 2.5 ns.

For More Information Circle No. 801



Diode-Pumped Rod Laser

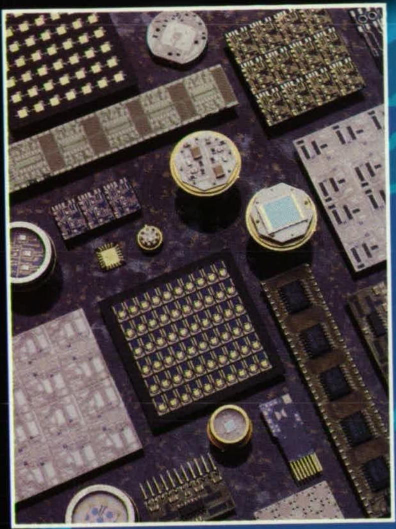
Cutting Edge Optronics Inc., St. Charles, MO, introduces the Stiletto, a sealed, compact 35-W diode-pumped Nd:YAG rod laser. The company says the product is a turnkey Q-switched laser system that will be useful for a wide range of near-infrared OEM, industrial, and scientific applications. The laser head, 1.75 in. in diameter and about 20 in. long, is housed in a sealed cylindrical tube that is the size of a typical HeNe laser. This makes possible using the laser with a wide variety of available HeNe mounts. An optional external screwdriver-adjustable mode control switches the laser to any one of three higher beam qualities, including TEM_{00} output.

For More Information Circle No. 802

Laser Diode Power Module

New from Analog Modules, Longwood, FL, is the Model 5705 isolated laser diode power module designed to drive diode loads for CW or pulsed diode-pumped solid-state laser applications. The module, which can be configured with either positive or negative output, delivers up to 2 kW of average power. With a 325-VDC input, it can deliver 40 A at 50 V, 20 A at 100 V, or 10 A at 200 V. For pulsed applications, the Model 5705 can be used in conjunction with an external switch to provide peak currents of up to 300 A. Weighing 3 lbs., the device measures 6.0 × 5.5 × 2.78 in.

For More Information Circle No. 803



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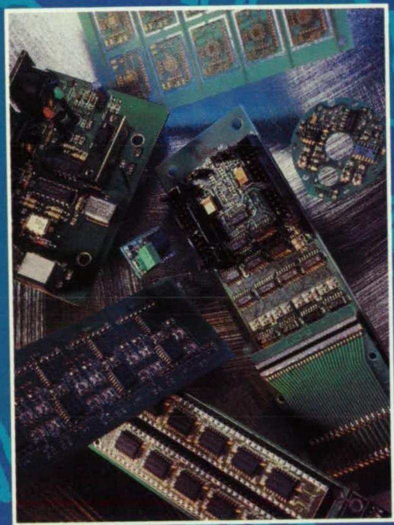

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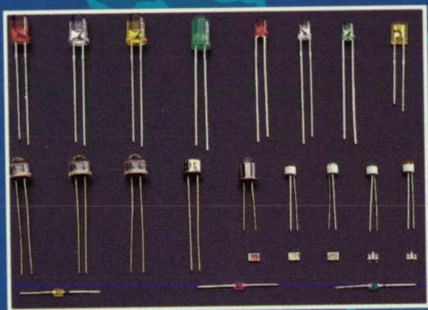

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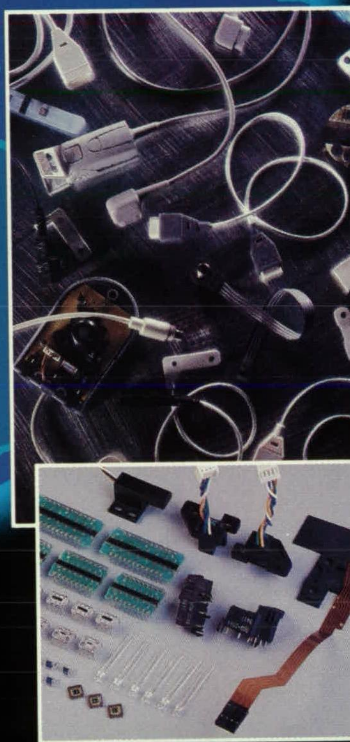


Circle 476

Pulse-tube Refrigerator Unit

The working fluid for this new device is helium, which is nontoxic to humans and harmless to the environment.

Marshall Space Flight Center, Alabama

The Pulse-tube Refrigeration unit offers a viable alternative to units that currently require chlorofluorocarbon (CFC) and hydro-chlorofluorocarbon (HCFC) working fluid. Pulse-tube Refrigerators use helium as the working fluid, which is nontoxic to humans and harmless to the environment.

Pulse-tube Refrigerators can be operated over a wide range of temperatures. These units can be used in numerous space and commercial refrigeration applications, including food refrigerator/freezers, laboratory freezers, and freeze dryers. Pulse-tube Refrigerators can also be used to cool detectors and electronic devices.

Pulse-tube Refrigeration, a variation of the Stirling cycle, is a relative newcomer compared to other refrigeration cycles.

The Pulse-tube Refrigerator is the first unit applied to the temperature range and load level needed for typical food freezers and laboratory freezers.

The design of the Pulse-tube Refrigerator unit was based on the Orifice Pulse-tube concept. First, the gas is compressed in the compressor. Next, it flows through the compressor aftercooler, where heat is rejected to a water-cooling loop. Then the gas flows through the regenerator, which is basically an economizer, conserving cooling from one cycle to the next. The gas then enters the cold-end heat exchanger where heat is added to the gas from the surroundings.

The gas finally enters the Pulse Tube, orifice, and reservoir. These three components produce the phase shift of the mass flow and pressure, which is necessary for cooling. The gas shuttles back and forth between the hot and cold ends rather than circulating continuously around a loop, as in some refrigeration cycles. Heat is lifted against the temperature gradient and rejected at the hot-end heat exchanger, which is also water-cooled.

The compressor designed and built for this unit is a dual-opposed-piston type. The displacement of these two pistons is 180° out of phase, to reduce vibrations. The compressor, which can be operated over a wide range of frequencies, is designed for operation at a nominal 60 Hz.

The compressor pistons are supported by helical mechanical springs which assist in producing harmonic motion and return the pistons to the needed null positions before startup. The pistons are supported inside the cylinders on dry lubricated, low-friction sleeve bearings. Each piston is attached to a separate moving coil, which is formed by wrapping copper wire around the end of a spool. When voltage is applied to a coil, the resulting current produces a force on the coil.

Optical encoders provide real-time readout of all piston positions. These encoders use a noncontacting interrupter scale between a light-emitting-diode source and sensors to detect motion. A tachometer pulse and direction signal are generated.

The cold-end and hot-end heat exchangers consist of fine mesh copper screens, fabricated in-house using proprietary techniques.

After design and fabrication, the Pulse-tube Refrigerator unit was subjected to numerous tests. A temperature of –45 °C was reached, which is well below the temperature required for food freezers.

Pulse-tube Refrigerators offer increased reliability, fewer moving parts, and much lower cold-end vibration than other spacecraft or commercial refrigeration concepts.

This work was done by W.G. Dean of Dean Applied Technology Co. for **Marshall Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category,* ***or circle no. 166*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Dean Applied Technology, Inc.
1580 Sparkman Drive #103
Huntsville, AL 35816
(205) 721-9550

Refer to MFS-26440, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improved Hybrid System Protects Airfoils Against Icing

This system includes an upstream thermal and a downstream electromechanical subsystem.

Lewis Research Center, Cleveland, Ohio

An improved hybrid thermal/mechanical system has been developed to protect airplane wings and other airfoils against the accretion of ice, which degrades aerodynamic performance. The system is designed with particular attention to advanced, high-performance airfoils, which exhibit significant loss of lift when their leading edges and adjacent areas become rough, as they do when ice accretes.

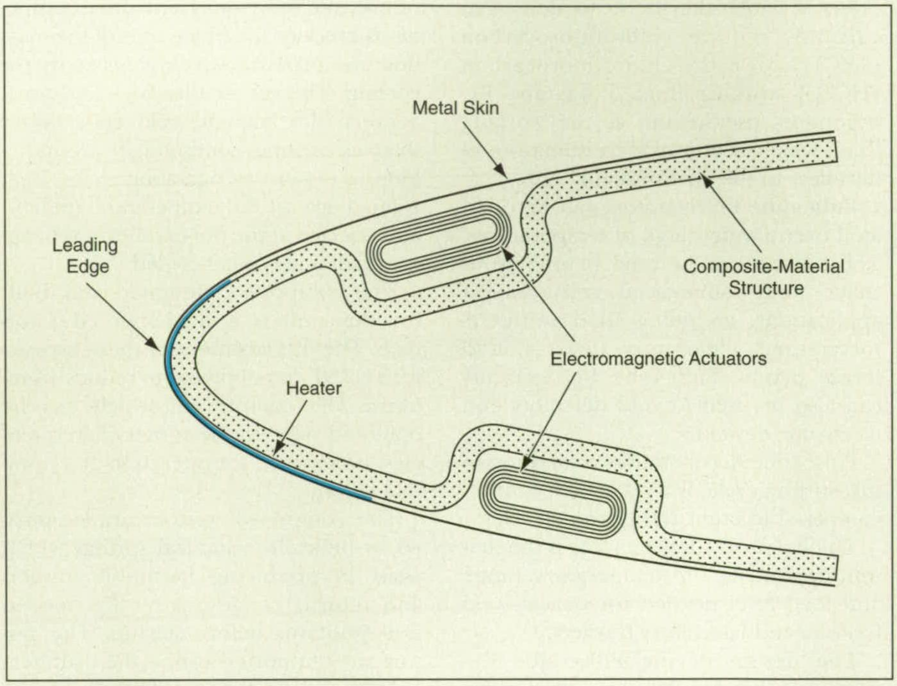
In aeronautical terminology, "anti-icing" denotes the prevention of icing, while "deicing" denotes the removal of ice that has already formed. Anti-icing is the only way to keep the leading edge and adjacent areas of an airfoil aerodynamically smooth in the presence of impinging supercooled water droplets. Deicing is adequate for the area sufficiently downstream of the leading edge,

but is not adequate for the leading-edge region because a typical deicing system is not effective until ice has accreted to some minimum thickness, and some residual ice sometimes remains after a deicing cycle.

In the most common approach to anti-icing, one heats the leading edge and adjacent roughness-sensitive area to evaporate the impinging supercooled droplets when flying through a cloud. However, the power demand of a fully evaporative anti-icing system is excessive for most light jet and regional turboprop airplanes. The present hybrid system was developed to enable the anti-icing and deicing of such airplanes at an acceptably low power demand.

This hybrid system includes an upstream thermal anti-icing subsystem, a downstream electromechanical deicing subsystem (see figure), and an electronic subsystem that controls the other two subsystems. The thermal subsystem heats (either electrically or by use of hot gas from the engine) the leading-edge region enough to prevent water from freezing, but not enough to evaporate most of the water. No such heating is performed in the area downstream of the leading-edge region for the following reasons: Water from the leading-edge region runs back along the surface in rivulets, so that most of the downstream area is dry most of the time. As a result, heating most or all of the downstream area in order to heat the wet spots would be inefficient, entailing excessive power demand.

The electromechanical deicing subsystem includes actuators inside the airfoil at downstream locations on the upper and lower airfoil surfaces. These are locations where ice forms by freezing of impinging droplets and of water that runs back from the leading edge. The actuators are basically electromagnetic coils to which large dc pulses are occasionally applied, as required, by discharging energy-storage capacitors, creating a rapid impulsive force. The electromagnetic force causes the actuators to expand perpendicularly to the skin. The airfoil skin momentarily deflects very slightly outward, with high level of acceleration, and returns to its original position. This is the actuation that removes the accumulated ice. Although the momentary pulse power is high, the average power consumed by the electromechanical subsystem is low.



The Heater Prevents Freezing of impinging supercooled water droplets in the leading-edge region. The electromagnetic actuators occasionally deflect the metal skin outward to knock off ice that accumulates downstream from the leading edge.

This work was done by Kamel Al-Khalil, Dennis Phillips, and Thomas Ferguson of Cox & Co., Inc., for **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/ Automation category,* ***or circle no. 110*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16412.

Evaluation of a "Smart" Aircraft Control Actuator

Benefits for future aircraft could include decreases in weights, costs, and electromagnetic susceptibility.

Dryden Flight Research Center, Edwards, California

An aircraft control actuator that incorporates self-contained control electronics has been installed in the F-18 Systems Research Aircraft and evaluated in flight tests. This "smart" actuator is a prototype of fly-by-wire servoactuators for future advanced aircraft.

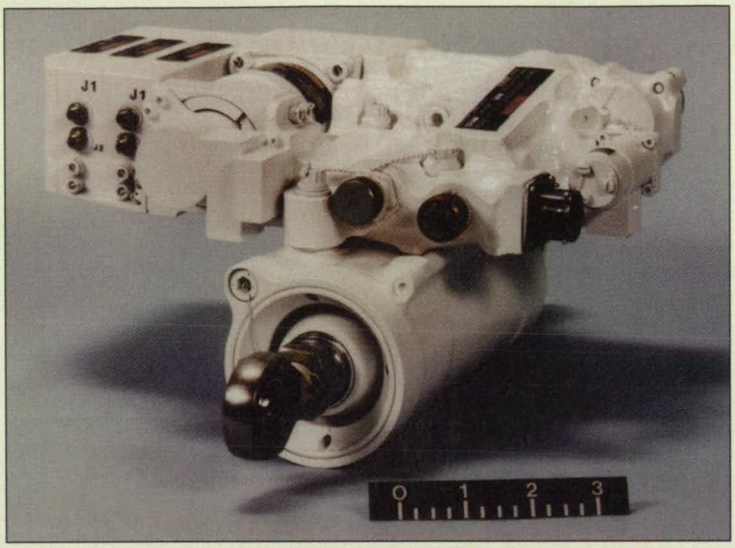


Figure 1. The **Smart Actuator** includes self-contained control electronics that perform functions that, in older systems, were performed within flight-control computers remote from actuators.

Fly-by-wire servoactuators now used in military and commercial aircraft are not "smart" in that they do not use self-contained control electronics. Generally, electronic control and monitoring of servoactuators on aircraft are accomplished within separate flight-control computers. As a result, a large amount of wire is needed to operate all the actuators on an aircraft. Especially in a large commercial aircraft, the weight of the wire is significant. Other disadvantages of such a fly-by-wire system include high cost of maintenance, vulnerability to interference by electromagnetic signals (including electromagnetic pulses), and the need for a unique flight-control interface for each actuator.

The smart actuator (see Figure 1) was designed to fit in the left aileron bay of the F-18 airplane. The smart actuator contains two independent electronic channels that perform actuator-control, fault-monitoring, and redundancy-management functions. Communication with the actuator has been simplified by use of standard serial data buses. Instead of wires, optical fibers are used as the communication media.

Installation of the smart actuator on the F-18 airplane necessitated two interface units. These units not only provide the electrical-to-optical interface between the smart actuator and the F-18 flight-control computers, but also provide data to the instrumentation system of the airplane. The use of the interface units also makes it unnecessary to modify the flight-control computers.

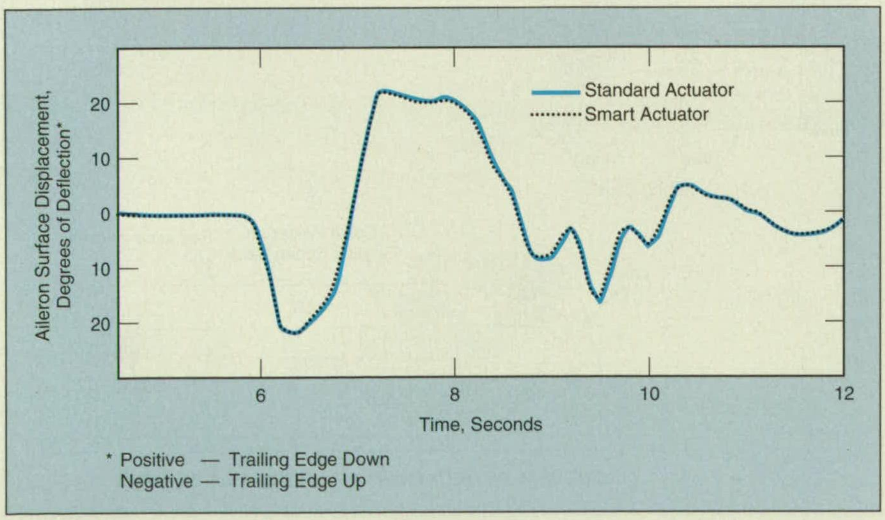


Figure 2. **Nearly Identical Performances** were exhibited by the smart actuator and the standard F-18 aileron actuator in a flight test. [Aileron reversal ±60° bank angle, 24 kft (7.2 km), 0.4 M, 88 q.]

The performance of the smart actuator throughout the flight-test program has been exceptional (see Figure 2). Likewise, the fiber-optic data buses used with the smart actuator performed well throughout flight testing. Moreover, the smart actuator performance was virutally identical to the F-18 production actuator. Although environmental tests revealed that the fiber-optic data buses were thermally sensitive, a maintenance-and-calibration procedure was developed to account for the sensitivities. Fiber optics were found to be satisfactorily reliable, and maintenance was easily performed. No anomalies occurred during the flight tests.

The development and flight testing of the smart actuator have proved that local control and monitoring of servoactuators is possible. Although sensitivities of the fiber-optic data buses were discovered, these sensitivities can be factored into future system designs. The use of fiber optics and serial data buses simplified integration of systems and provided valuable information regarding reliability and maintainability of fiber optics on aircraft. In addition, the use of fiber optics may translate to decreased weights, decreased costs, and decreased electromagnetic susceptibility for future aircraft.

This work was done by Kari Alvarado, Denis Bessette, Dorothea Cohen, Bill Fredriksen, Gordon Fullerton, Don Hermann, Linda Kelly, Doug Lindquist, Dick Klein, Bill McGrory, Harry Miller, Cynthia Norman, Lyle Ramey, Mauricio Rivas, Karla Shy, Joel Sitz, Daryl Townsend, and Eddie Zavala of **Dryden Flight Research Center***; Karen Richards of HSI; Gavin Jenney and Bruce Raymond of Dynamic Controls, Inc.; Dave Dawson and Major Dennis Trosen of the U. S. Air Force Wright Laboratories; Sean Donley of the U. S. Navy; and Bob Heagey and Bob Deller of HR Textron. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category,* ***or circle no. 157*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). DRC-96-73*

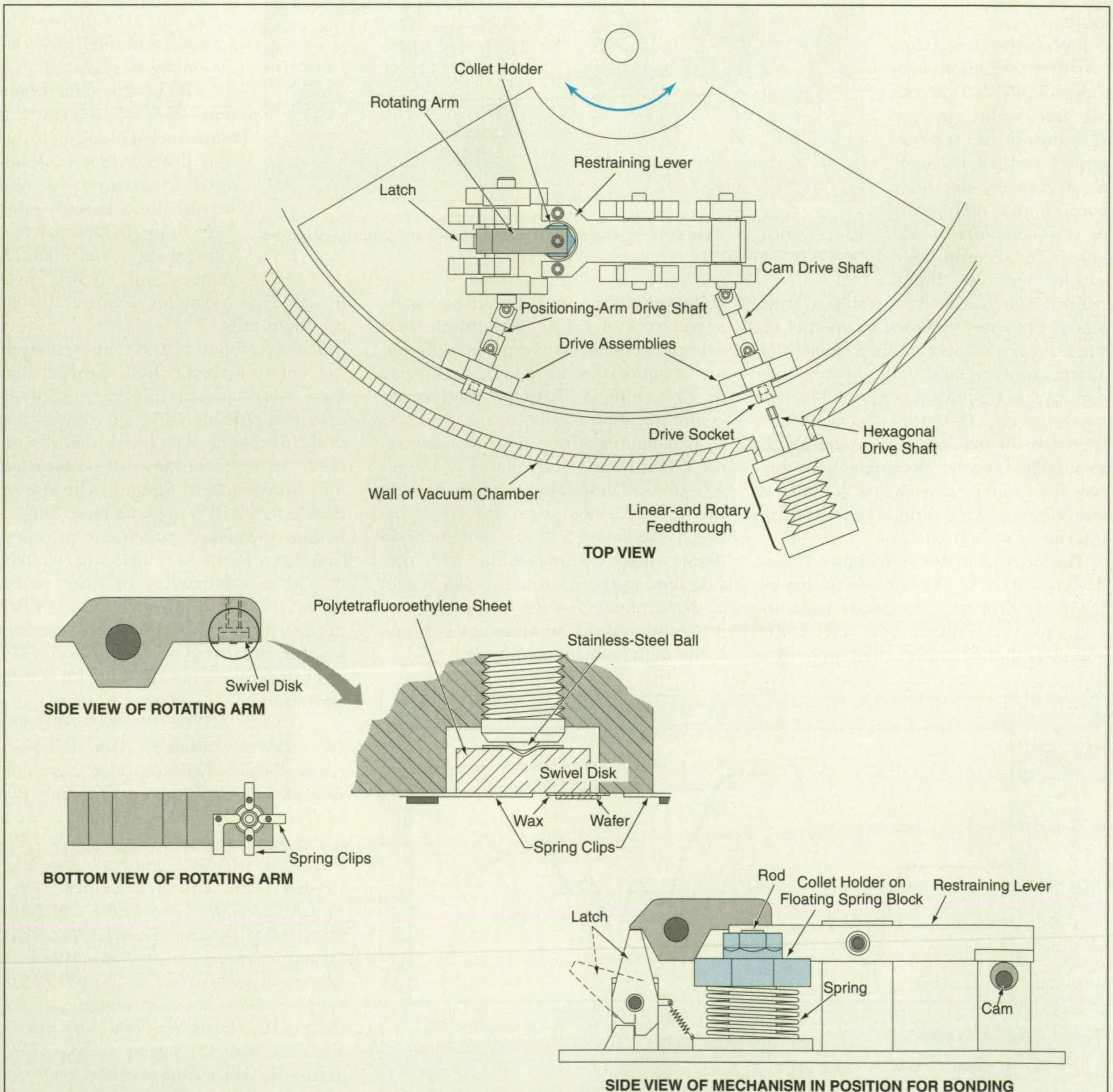
Manufacturing/Fabrication

Apparatus for Coating and Cold Welding in Vacuum

Vacuum need not be broken between the coating and cold-welding processes.

Lewis Research Center, Cleveland, Ohio

The figure illustrates selected aspects of a manually actuated apparatus for use in coating two small objects with suitable metals, then forcing the two objects together at the coated flat surfaces with uniform pressure to cold-weld them to each other. The design of this apparatus provides for all steps of the coating and cold-welding processes, including intermediate steps of manipulation between these processes, to be performed in a vacuum, with no need to break vacuum



The **Wafer Can Be Positioned** facing upward toward a metal-deposition source, the turntable can be turned to bring the rod and disk to different metal-deposition sources, and the metal-coated wafer can be pushed down onto the rod for cold welding, all without breaking vacuum.

between the processes as in older methods of coating and cold welding. By maintaining vacuum through all processing steps, one prevents the formation of surface oxides, which interfere with cold welding. Maintaining vacuum also prevents the formation of pockets of trapped gas, which render the bond nonuniform.

In the original application for which the apparatus was designed, the objects to be joined are components of an ultrasonic transducer; namely, a piezoelectric (e.g., lithium niobate) wafer as thin as 0.001 in. (25 μm) and a round sapphire rod with a flat surface (to mate with the wafer) at one end and a concave focusing surface at the other end. The faying surfaces of the rod and disk must be coated with thin layers of chromium, then gold, then indium, by sputtering or vapor deposition in a vacuum. Then the wafer is pressed onto the end of the rod with a pressure of about 300 kg/cm^2 (about 0.1 MPa) to cold-weld the rod and disk together at the indium surface layers. Thinness and uniformity of the bond layers and uniformity of the cold-weld joint are necessary for proper acoustic performance.

The apparatus includes a collet that holds the sapphire rod and a rotating arm that contains a swivel disk, on which the wafer is held by a layer of wax. The arm enables the initial pickup of the prealigned wafer, the orientation of the wafer facing a metal-deposition source, and the repositioning of the wafer for subsequent bonding to the rod. During coating with metal, both the rod and the wafer are oriented with the bonding surfaces to be coated facing the source of the metal. The chromium, gold, and indium layers are deposited from three different sources. The apparatus includes a turntable so that the rod and wafer can be positioned below each of the three sources in sequence.

The collet is mounted in a spring-loaded holder, the springs of which are preadjusted to provide the appropriate bonding force. The springs are compressed and restrained by a cam-actuated lever. The cam is driven by a linear-and-rotary vacuum feedthrough that enables actuation without breaking vacuum. The feedthrough can be made to engage a cam socket when the angular position of the rotary table is such that the cam socket and the feedthrough are aligned with each other.

A similar feedthrough and cam-actuation mechanism is provided for the positioning arm. The arm is initially set in the coating position. After deposition of the three metal layers, the arm is rotated, by use of this mechanism, to push the wafer down onto the rod in the collet. The swivel disk provides limited freedom of tilt to allow the wafer to align itself with the tip of the rod when the wafer and rod are pushed together. A latch locks the arm into position for bonding. A restraining cam is rotated to unload the spring compression from a restraining lever, allowing the spring to press the wafer and rod together.

After the pressing, the vacuum system can be opened. Spring clips that hold the swivel disk in place and the collet that holds the rod in place are loosened, making it possible to remove the bonded parts with the swivel disk still attached to the wafer by wax. The swivel disk is released by gently heating the parts to melt the wax.

This work was done by Richard Oeftering and Floyd Smith of **Lewis Research Center.** *For further information, access the Technical Support Package (TSP),* ***free on-line at www.nasatech.com*** *under the Manufacturing/Fabrication category,* ***or circle no. 106*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7-3, 21000 Brookpark Rd., Cleveland, OH 44135. Refer to LEW-15922.

Carbon/Carbon Shield/Antenna Structure

This strong, lightweight structure could withstand high temperature.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed lightweight, off-axis reflector structure for a microwave communication antenna would be made of a carbon/carbon composite material. The structure was conceived for use aboard the Solar Probe spacecraft, where it would also serve as a shield to protect the spacecraft against solar radiation at perihelion. The basic concept of the carbon/carbon reflector structure could be also adapted to design lightweight, strong, off-axis reflector structures for antennas to be used on Earth.

Carbon/carbon was chosen as the class of structural materials because such materials offer a combination of light weight, high strength, good radio-frequency (RF) reflectance properties, and low mass loss at high temperatures. Results of tests of candidate materials suggest that the proposed shield/antenna structure would function well at a temperature greater than 2,000 K. The major drawback of materials in this class is that they are expensive.

In the original Solar Probe application, the dual use of the structure as a solar shield and antenna reflector was made possible by a fortuitous combination of optimum shield and antenna shapes that was effected by designing the spacecraft trajectory to obtain Sun/spacecraft/Earth quadrature at spacecraft perihelion. The combined shield/antenna would also enable a reduction of overall spacecraft diameter: According to an older design concept, the solar shield would be a separate, conical structure and the antenna reflector would lie within the shadow of the shield. The overall spacecraft diameter according to that concept would be 4 meters. The overall diameter according to the proposed simplification would be reduced to 1 meter, and the overall mass and cost of the spacecraft would be concomitantly smaller. Of course, whether or not such simplification and reduction in size could be effected in other applications would depend on the geometries and design and operational requirements specific to those applications.

This work was done by James Randolph of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 148*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20318

Software Models Processes in a Gaseous Chemical Reactor

A simple, volume-averaged model provides guidance for designing reactors.

Ames Research Center, Moffett Field, California

The Simple Analysis of Materials Processing Reactors (SAMPR) computer code is meant for the analysis of plasma and nonplasma processes used in manufacturing semiconductors. The code can also be used to analyze any chemical-processing reactor with gaseous (but not liquid) streams.

The code implements a mathematical model that consists of balance equations for the total mass, mass of individual chemical species, and gas energy. In the case of plasma reactions, a plasma power balance is also included.

The balance equations are volume-averaged; in other words, they represent a zero-dimensional (0-d) analysis. For this analysis to be valid, the reactor contents must be well mixed and not exhibit significant gradients of species concentrations or gas temperatures in any part of the reactor. Such perfect mixing conditions can be found in reactors used in chemical process industries. Such ideal conditions may not exist in reactors used

for etching, deposition, annealing, or performing any other functions in the course of manufacturing integrated circuits. Nevertheless, approximate solutions to somewhat idealized reactor conditions may be valuable in estimating overall conversion efficiency of feedstock, effluent concentrations, and energy utilization.

SAMPR provides volume-averaged electron density, electron temperature, and concentrations of radicals and ions as functions of pressure, input power, and flow rates. Obviously, detailed information on the departure from uniformity of the plasma, and on fluxes of radicals and ions near a wafer in the reactor is lost in such a global model, but quantitative behavior of the plasma as a function of system parameters or the so-called "scaling laws" can be obtained very rapidly. Generation of such valuable knowledge with minimal computational resources is the attraction of this simple approach.

Also, the results obtained from a 0-d model can provide guidance for further multidimensional simulations. Usually, in a semiconductor-processing situation, the numbers of chemical species and reaction pathways are large. Multidimensional analysis with a large set of reactions and species is computationally intensive. A 0-d analysis in such a case can be used effectively in a systematic study to generate a "reduced chemistry set" that provides reasonable results.

This work was done by M. Meyyappan of **Ames Research Center** *and T. R. Govindan of Applied Research Laboratory. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 142*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center; (650) 604-5104. Refer to ARC-13392.

Automated Calibration of Temperature Transducers

John F. Kennedy Space Center, Florida

An automated system of laboratory equipment and computer hardware and software reduces the time that technicians must spend in calibrating temperature transducers. The laboratory equipment includes a controlled-temperature bath, two digital multimeters for processing the outputs of two temperature transducers at a time, and standard interface bus circuitry for controlling and monitoring the bath and the multimeters. The operation of the laboratory equipment is controlled by equipment-specific software on a computer that runs Windows 95 and is equipped with a standard general-purpose interface bus circuit card. A technician specifies data points for calibration, and thereafter the software controls the calibration process. The process includes timed advances to subsequent temperatures and holding periods for stabilization at calibration temperatures, with a sampling period of 1 second. The technician can leave the system unattended during the calibration process. Using manual techniques, it usually takes about half a day to calibrate two temperature transducers at three data points; using this system, it takes about two hours.

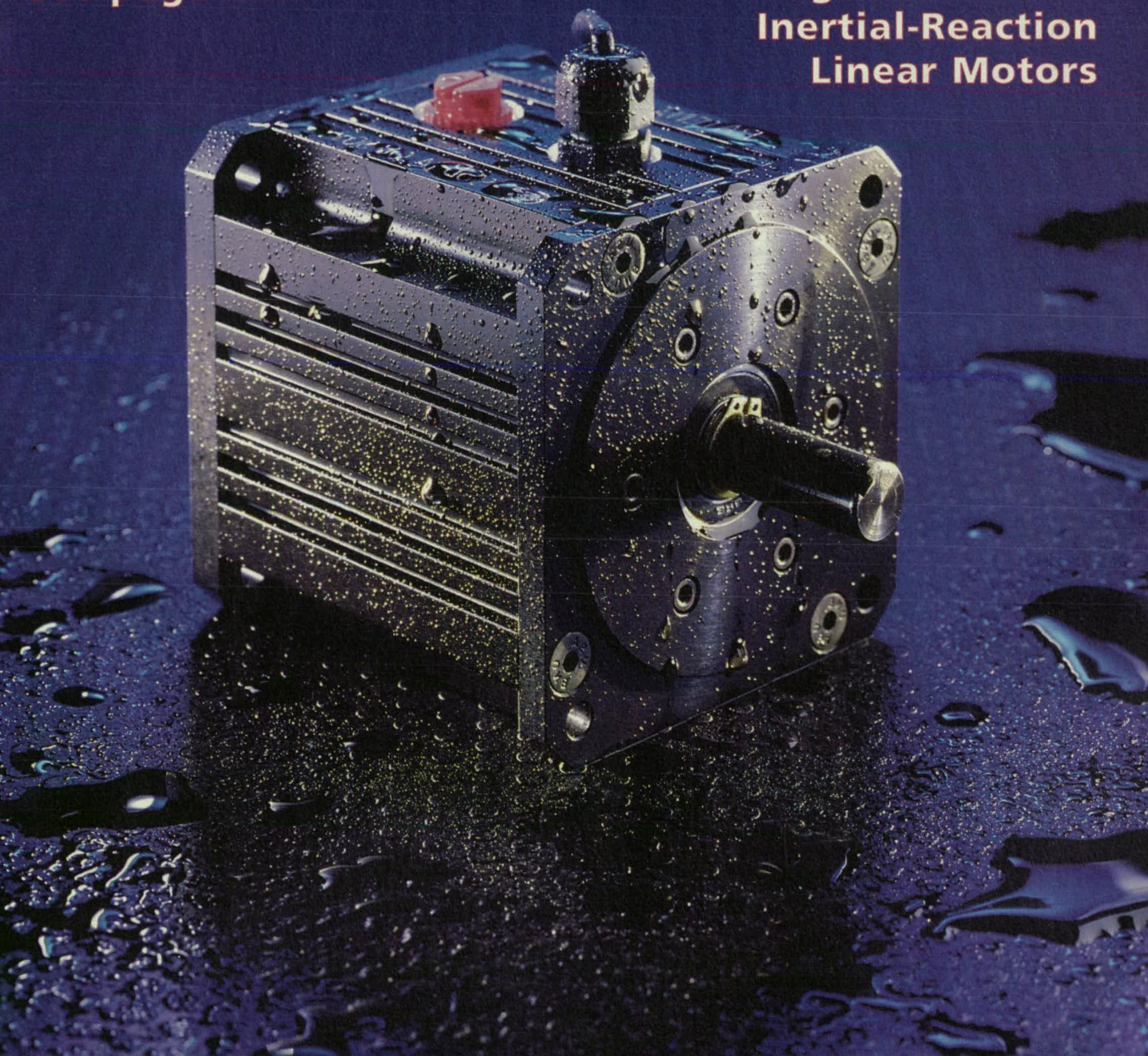
This work was done by Timothy Joe Ragain of United Space Alliance for **Kennedy Space Center**. *No further documentation is available. KSC-11988*

Motion Control Tech Briefs

New Motion Control Products — see page 20b

Integrating Motion and Sequential Control

Magnetostrictive Inertial-Reaction Linear Motors



For More Information Circle No. 655

Motion Control Tech Briefs

Motion Control Tech Briefs Supplement to *NASA Tech Briefs* June 1998 Issue Published by Associated Business Publications

FEATURE

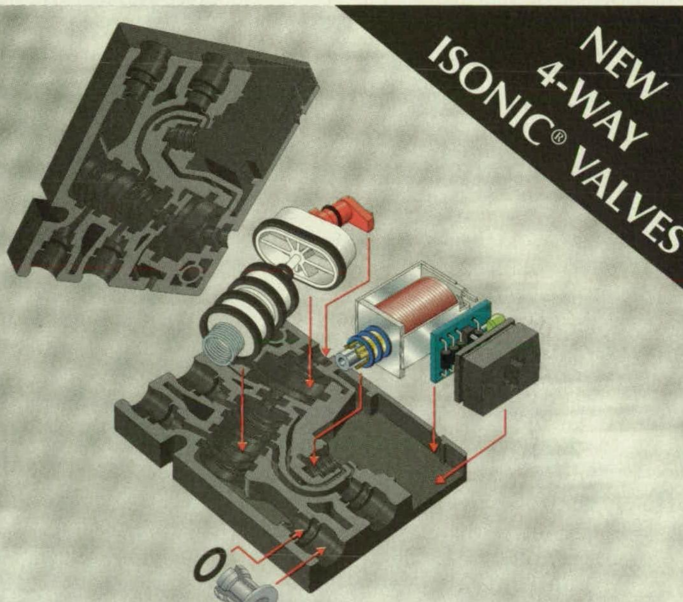
MOTION CONTROL TECH BRIEFS

DEPARTMENT

On the cover:

Electroid Co. of Springfield, NJ, offers the SSB series of front-end brakes specifically designed as a solution to braking applications on stepper and servo motors. See page 20b for new motion control products.

Photo courtesy Electroid Co.



INTEGRATION OF MOTION AND SEQUENTIAL CONTROL

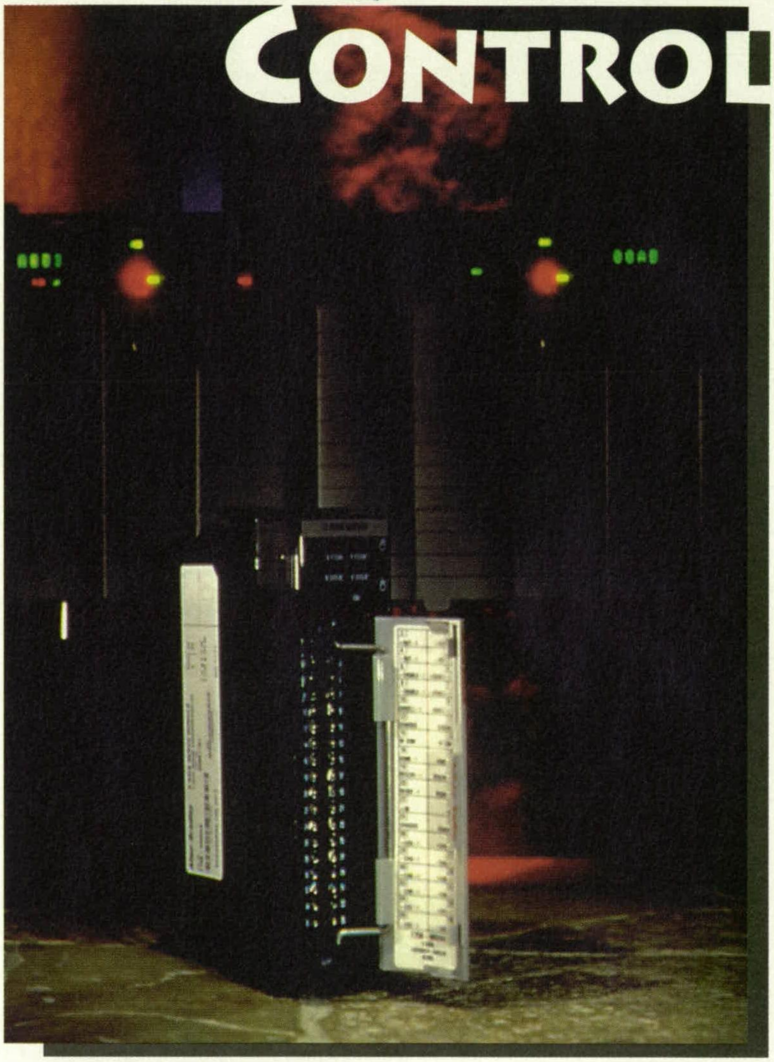


FIGURE 1. The 2-Axis servo module (front) for the ControlLogix system (back).

ROCKWELL AUTOMATION'S NEW APPROACH INTEGRATES MOTION CONTROL ON A COMMON HARDWARE AND SOFTWARE PLATFORM.

Typically, performing motion control functions requires the use of a dedicated motion controller separate from an application's programmable controller. These two devices must then be linked together using hard-wiring, a serial interface, or some other communication interface. The resulting system is frequently difficult to program and maintain, and may suffer performance problems as well. For example, users must write separate application programs for both controls, typically with two different programming packages.

Rockwell Automation's new modular approach involves a controller and one or more motion modules, all residing in the same hardware chassis as the controller. The controller plays an expanded role, to include motion instructions embedded in firmware. The general-purpose programming software provides full motion programming and configuration support for the controller.

CONTROL COMPONENTS

The three components of this new approach are:

- ◆ Controller(s). The controller is an Allen-Bradley Logix5550™ controller from Rockwell Automation. The controller is part of the Allen-Bradley ControlLogix™ system, a control architecture for sequential, process, and motion control applications. As the heart of this approach, the controller performs all of the high-level motion command execution and motion trajectory planner functions, in addition to the traditional sequential control (counting, timing, shifting) functions. The 27 motion commands embedded on the controller support a range of motion functions from simple point-to-point moves to more complex ratioing moves. These motion commands are based on those found in other commonly used motion controllers. Up to eight servo modules (or 16 axes) can be controlled by a single controller.
- ◆ Motion modules. The motion module is the 2-axis servo module for the ControlLogix system (Figure 1). It provides two channels of 16-bit analog output, and two channels of quadrature encoder input. This allows it to connect to a wide variety of servo drives. All needed configuration parameters are sent to the motion module by the controller. As a result, the motion module does not require separate configuration or programming. The module contains a digital signal processor (DSP) that provides very fast 100-µs fine trajectory planner, position loop, and velocity loop closure.

Continued

Miniature DC Servo Actuators Mini RH Series

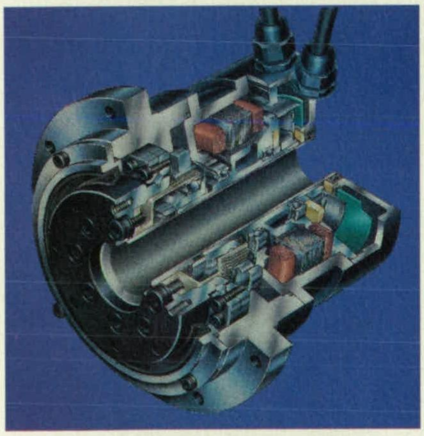
HD Systems offers a line of miniature DC servo actuators for use in applications such as robotics, instrumentation, and factory automation where precise motion control is required. The actuators combine zero backlash harmonic drive gearing with rare-earth magnet DC servo motors to provide both high torque and positional accuracy better than 2 arc-minutes. Rated torques of 2.6 thru 56 in-lb and rated speed of 15 thru 60 rpm are available depending on frame size and gear ratio. The smallest actuator measures just 20 mm in diameter. Encoders and/or tachometers are available as an integral part of the actuator.

HD Systems, Inc. - (800)231-HDSI

New, Hollow Shaft Gearing SHF Series

Featuring a through-bore up to 70 mm in diameter, the SHF Series component sets and gearheads enable the design engineer to pass shafting, wire bundles, or other components directly through the center of the gear. The new SHF Series provides high accuracy in a compact design. This unit design is both axially shorter and lower in weight, as compared to conventional harmonic drive gearing. This is accomplished by using HD Systems patented "S" tooth profile. Rated torques up to 6590 in-lb and positional accuracy better than 2 arc-min can be achieved. Gear reduction ratios of 50:1 through 160:1 are available in a single stage.

HD Systems, Inc. - (800)231-HDSI



Hollow Shaft DC Brushless Actuators

The FHA Series of actuators feature a through-bore up to 45 mm in diameter and provide high torque and exceptional positioning accuracy. This performance is achieved in a compact design using a patented "S" tooth harmonic drive gear coupled to a DC brushless pancake motor with integral electronic commutation and a high resolution encoder. Rated torques up to 1730 in-lb and positional accuracy better than 1 arc-minute can be achieved. The FHA Series is available in five frame sizes, ranging from 128 to 300 mm in diameter, and 116 to 248 mm in length.

HD Systems, Inc. - (800)231-HDSI

For More Information Circle No. 657

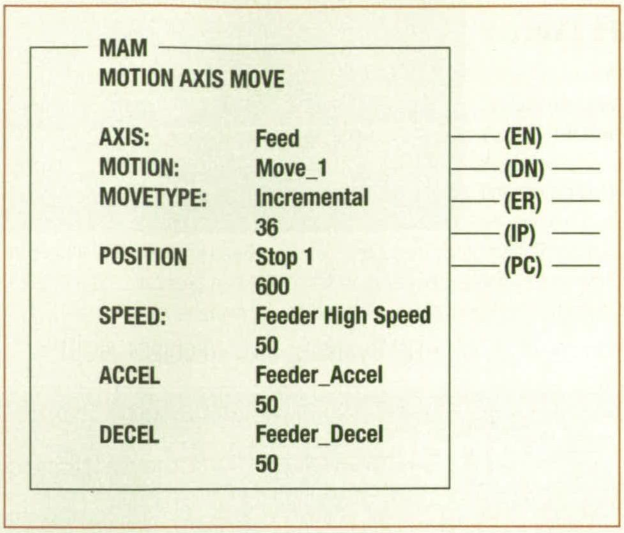


FIGURE 2. Five motion instruction tabs provide access to the 27 motion commands. For example, executing a move is a simple matter of placing a move command in a ladder logic rung by selecting the "Motion Move" tab and clicking on the MAM instruction and entering the specified parameters.

- Programming environment. The standard programming package for the controller, RSLogix5000™ software, also provides complete programming, configuration, and commissioning support for motion control. This allows users to easily perform sequential control and motion control programming within a single environment. When a motion module is added to the system, the user is stepped through configuration of each axis, including initiation of autotuning for determining axis gains and dynamics. All configuration and application program information is downloaded to the controller for execution.

SYSTEM OPERATION

Using this approach to perform multi-axis closed-loop control of a servo system consists of two major parts. The first is a high-speed Motion Task that runs in the controller and generates position and velocity trajectory information based on commands received from motion instructions executed in the application program (Figure 2). The position and velocity trajectory information is then sent transparently, over the backplane of the hardware chassis, to one or more motion modules, where a 100-µs fine trajectory planner, position loop, and velocity loop is closed. The motion module returns position, velocity, and status information to the controller, where it can be used by the trajectory planner or application program. A service is supported in the chassis that fully synchronizes one or more controllers and up to 16 two-axis motion modules per controller.

The second major part of the motion system involves the use of the controller to perform asynchronous services to configure the motion system or to monitor the current state of the system. The controller's Motion Task exists in one of the three states of operation: idle, configuration, or run. On power-up, the Motion Task is in the idle state. Upon receipt of a service request, the Motion Task checks to see whether the axis instance is within an allowable range. If it is, the system transitions to the configuration state. Here, attributes such as the motion module's slot number are checked for duplication to prevent a user from associating multiple axis instances with a specific motion module. In the run state, the motion system is fully configured, and the loop is closed upon request by the motion module.

BENEFITS ARE SEVERAL

The benefits of this new approach include higher system performance, faster application development and integration, and easier maintenance. Performance is increased because the controller and motion module reside on the same hardware chassis, for faster communication than is possible over a multinode network.

Performance is enhanced because the elements that usually require tight synchronization—sequential control and motion command execution/trajectory planner—are executed on the controller, while the high-speed position and velocity loop are closed on the motion module (Figure 3). Because of this modular, distributed approach, it is possible to maintain fast position- and velocity-loop closure while maintaining tight synchronization of the logic and motion command execution/trajectory planner functions. In cases where fast scan times or faster trajectory planner update rates are required, additional controllers can be placed in the chassis.

Startup and maintenance times are decreased. Synchronizing the controller and motion no longer requires two separate "boxes" connected over a network, but instead is handled in a manner transparent to the user. The system's integrated programming environment enables faster development of application programs, more complete integration, and improved ease of maintenance because the same programming environment is used for both motion and sequential control during development and operation of the system.

This work was done by Gregg Meinert of Rockwell Automation, Mayfield Heights, OH, and Bob Hirschinger, Rockwell Automation, Mequon, WI. For more information, please call (800) 223-5354, ext. 0733.

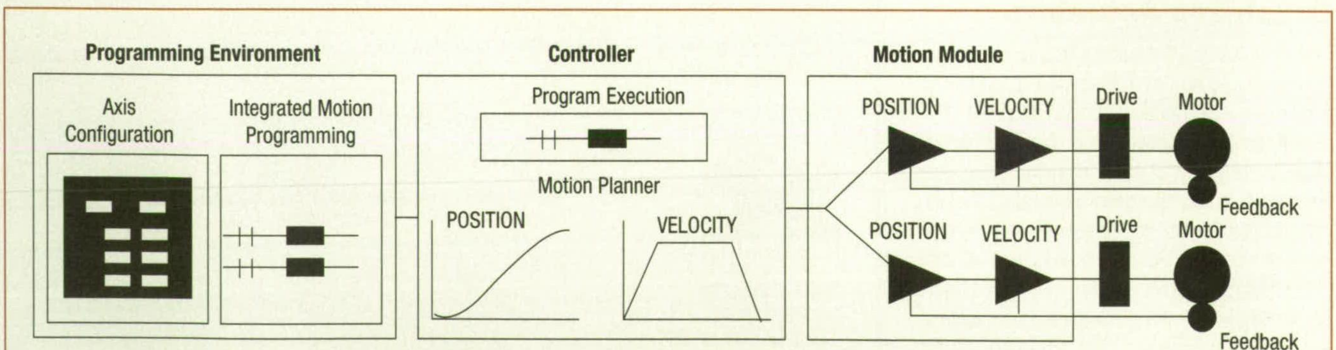


FIGURE 3. The three components of an integrated motion system are the programming environment, controller, and motion module.

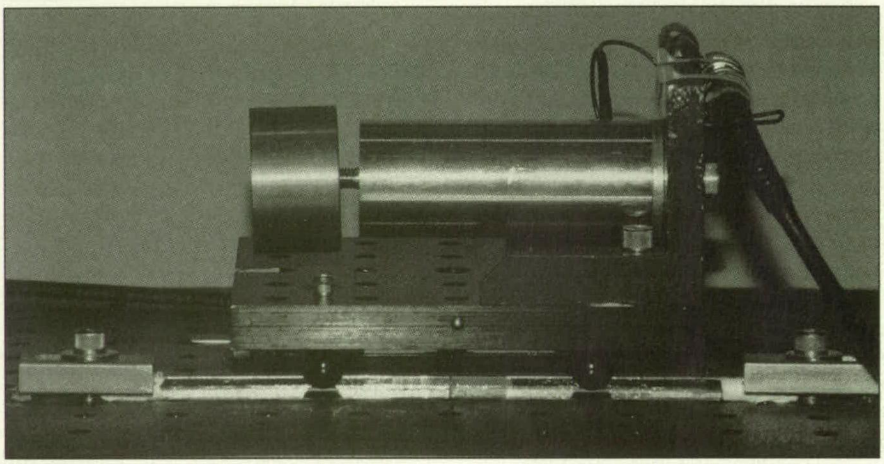
Magnetostrictive Inertial-Reaction Linear Motors

Fine positioning could be achieved at temperatures from near absolute zero to ambient.

NASA's Jet Propulsion Laboratory, Pasadena, California

Linear-translation motors containing inertial-reaction masses driven by magnetostrictive actuator elements are undergoing development. These motors could be used to make fine position adjustments in diverse scientific and industrial instruments that operate at temperatures ranging from near absolute zero to room temperature; for example, they could be used to drive translation stages in scanning tunneling microscopes that operate at liquid-helium temperature (4 K), or to move cryogenic-temperature optical elements that must be located at long but precise distances from each other (as in interferometers). [These motors should not be confused with proposed magnetostrictive motors that would move in "inchworm" fashion and would be used for similar purposes, described in "Magnetostrictive Actuators for Cryogenic Applications," *NASA Tech Briefs*, Vol. 20, No. 3 (March 1996), page 84.]

An inertial-reaction motor includes a platform that slides along a pair of tracks. One end of an electrically driven linear actuator is mounted on the platform, and a substantial mass (the inertial-reaction mass) is attached to the other end. The actuator can be made to move the mass, rapidly or slowly, along a short range parallel to the track. If the mass is driven with sufficient acceleration that the reaction force overcomes the friction between the platform and the track, then the platform moves a short distance along the track. If, following a rapid stroke in the forward direction, the mass is driven relatively slowly in the reverse direction, then the reaction force is insufficient to overcome friction, and thus the platform remains in the position to which it moved during the forward stroke. By driving the actuator with a sawtooth waveform at the appropriate amplitude and frequency, one can cause the actuator to repeat this action and thus move the platform in a succession of small steps. The total distance traveled can range from a single step to the length of the tracks, which could be as much as 1 m or more in some instruments. The motion can be reversed by inverting the waveform driving the actuator.



This **Magnetostrictive Inertial-Reaction Motor** is a proof-of-concept model that has been shown to produce incremental motions as small as 100 nm.

The principle of operation as described thus far does not call for any particular type of linear actuator. Heretofore, inertial-reaction motors have been constructed with piezoelectric actuators. However, piezoelectric actuators exhibit diminished performance as temperature decreases into the cryogenic range; at liquid-helium temperatures (about 4 K), piezoelectric actuators perform poorly.

Unlike piezoelectric actuators, magnetostrictive actuators perform well at temperatures from ambient down to 4 K and below; indeed, magnetostrictive actuators reach their performance peaks at cryogenic temperatures, while at room temperature, they produce strokes about 7 times as large as those of comparable piezoelectric actuators. Moreover, if the magnetostrictive linear actuators for cryogenic inertial-reaction motors are constructed with superconducting solenoids, then the conversion of electrical to mechanical energy could be more efficient.

The feasibility of magnetostrictive inertial-reaction motors has been demonstrated in tests of such a motor built with a commercial room-temperature magnetostrictive actuator (see figure). Incremental motions as small as 100 nm have been achieved. With further development, it should be possible to achieve increments as small as 10 nm.

This work was done by Christian Lindensmith and Robert Chave of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category,* ***or circle no. 134*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). NPO-20153*

Device for High-Pressure Fused Deposition of Engineering Polymers From Feed Rods

New technology builds a solid object from true functional engineering materials.

Marshall Space Flight Center, Alabama

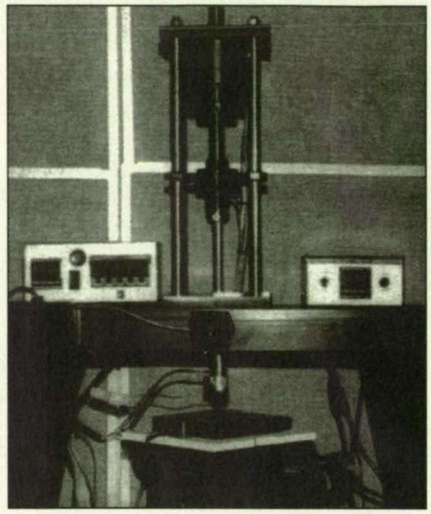
A more versatile delivery system for fused deposition has recently been developed. This system uses a very stiff, precise, and compact actuator to drive a small piston/cylinder extruder that has a heated nozzle. Because feed rods are used as the feed material, this newly developed delivery system does not have the materials limitations of conventional delivery systems.

This innovative technology is a mechanical assembly that can achieve high extrusion pressure that can be constructed in a compact enough form to retrofit existing fused deposition sys-

tems. The heart of this mechanical system is the combination of a hollow cylindrical servo motor and a ball screw, which are used to directly drive the piston of a piston extruder. The end of the screw is secured on a plate, which slides on four posts to provide counterrotation. This plate also prevents any axial misalignment of the screw and houses the load cell. The four posts provide a frame that attaches to a top plate to support the motor and a bottom plate to support the cylinder of the piston extruder. These elements form a very stiff mechanical linkage with very low lag or backlash and produce very precise volumetric displacement of material.

The cylindrical pancake motors for this invention were designed to eliminate gear reductions and avoid backlash in direct- drive equipment. Because the stator has been moved to the outside of the rotor, these motors produce very high torque at extremely low and controlled angular velocities. The increased radius and mass of the rotor translate to very high torque and rotor inertia. Also, the cylindrical motor is hollow, which allows the ball nut to fit inside the motor. This makes the actuator assembly very compact.

Two configurations of the high-pressure deposition were fabricated. One configuration was designed to retrofit into a Statasys Fused Deposition Modeler (FDM). The second configuration was designed for an Advanced Ceramics Research, Inc., (ACR) in-house fused deposition system. In the FDM, the head is moved in the horizontal plane and material is deposited onto a base that is moved vertically. In the ACR in-house system, the head is mounted on a stationary bridge and material is deposited onto a base which is moved in the horizontal plane and vertically beneath the head. The ACR system has more piston displacement, but the basic design of both units is the same.



A completed ACR in-house **High-Pressure Fused-Deposition System** is depicted in this photo.

This innovative technology has been used to free-form a number of important functional materials, such as polyaryletherketone, polycarbonate, thermoplastic polyurethane, and polylactic acid/polyglycolic acid block copolymer. This delivery system has also been used to fabricate green bodies that were subsequently fired to high density, including alumina, yttria stabilized zirconia, and silicon nitride.

Testing of these materials showed that the mechanical properties of the materials systems developed with this new invention greatly surpassed those of other free-formed polymer materials.

This work was done by Peter Creegan, Robert Hoffman, and Gabriel Chambers of Advanced Ceramics Research, Inc., and Kevin Stuffle of Materials and Machines, Inc., for **Marshall Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Manufacturing/ Fabrication category,* ***or circle no. 135*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-26446.

FEDLABS FORUM

News from the Federal Laboratory Consortium for Technology Transfer (FLC) — the nationwide network of federal labs that provides the forum to develop strategies and opportunities for linking technology with the mission and the marketplace.

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THE FLC LOOKS AHEAD...IN AGRICULTURE, NUTRITION, TRANSPORTATION...

Seeing the Forest *and* Trees...USDA Forest Service Chief **Mike Dombeck** unveiled the Natural Resource Agenda for 2000 and beyond to meet the needs of Americans, as well as protect the environment. The agency is committed to watershed restoration and maintenance, sustainable forest ecosystem management, forest roads and outdoor recreation.

Fungus Foiled...A new and better test developed by Agriculture Research Service researchers that detects a harmful fungus (*Phomopsis Longicolla*) causing seed decay and discoloration in harvested soybean seeds, can be easily adapted for commercial use. Isolating a unique genetic sequence (DNA) in the fungus, the ARS method can distinguish the fungus from similar fungi infecting soybean seeds. **Glenn Hartman**, 217/244-3258.

Soil Saver...1997 FLC Award-winner saved about one million tons of soil on an estimated 50,000 acres of furrow-irrigated land in its first year of commercialization. The novel furrow-irrigation erosion control technology halts irrigation-induced erosion by small additions of water-soluble polyacrylamide (PAM) to irrigation water. The developer, the USDA-ARS Northwest Irrigation and Soils Research Lab of Kimberly, Idaho, worked with CRADA partner Cytec Industries. **Rick Lentz**, 208/423-6531.

HOPE Has Heart...U.S. Army's National Automotive Center (NAC) and the Tank-Automotive and Armaments Command (TACOM), of which it is a part, work with Focus: HOPE, a civil/human rights organization of over 700 employees, 49,000 supporters. HOPE's food and technology training programs—FAST TRACK, Machinist Training Institute, Center for Advanced Technologies (CAT)—help solve area economic/racial problems and provide skilled workers for commercial enterprises. Together they developed a metal matrix machining process involving piston prototypes for military and commercial vehicles, a CRADA for advancing machine tool technologies, and many other manufacturing projects. CAT and U.S. Army, partners since 1989, continue with new, challenging ventures. **Joe Petrosky,** Technical Manager, 313/494-4274.

NAC Track... Your company can work with the NAC in Michigan to develop dual-use automotive technologies to meet both industry and government needs. NAC works with industry giants as well as start-ups to improve vehicle performance, safety and endurance while reducing design, manufacturing, operation and maintenance costs. TACOM/NAC also developed the Hybrid HMMWV, the hybrid electric drive approach project for military ground vehicles and the commercial automotive market, with significant performance improvements. Questions? Call NAC representative, **810/574-5793**.

Web Work... The Agricultural Research Service (ARS) Quarterly Report, at **http://www.ars.usda.gov/is/qtr/**, provides updates on current USDA projects, with ARS patent info and contact scientists familiar with each project. For 13,000 ARS research summaries, check ARS TEKTRAN database, **http://www.nalusda.gov/ttic/tektran/tektran.html**. Or **http://cristel.nal.usda.gov:8080**, the USDA Current Research Information System (CRIS) of nearly 33,000 project summaries, and USDA's latest progress reports, recent publications.

Navigation and Control of Continuous Mining Systems

Advanced technologies improve the accuracy of continuous mining systems.

National Institute for Occupational Safety and Health, Pittsburgh, Pennsylvania

Research conducted at the Pittsburgh Research Center (formerly U.S. Bureau of Mines) developed technology that will allow computer-assisted operation of mechanized equipment normally used in underground room-and-pillar coal mining, while permitting workers to be located away from the hazardous coal extraction area (the face). Advanced navigation and control technologies developed for underground room-and-pillar and highwall coal mining can be applied to commercially available mining equipment. The technology being developed uses off-the-shelf components, minimizing the effort required to adapt it to mining equipment. Because the new developments are completely modular, only the modules required in a particular application need be used on the system.

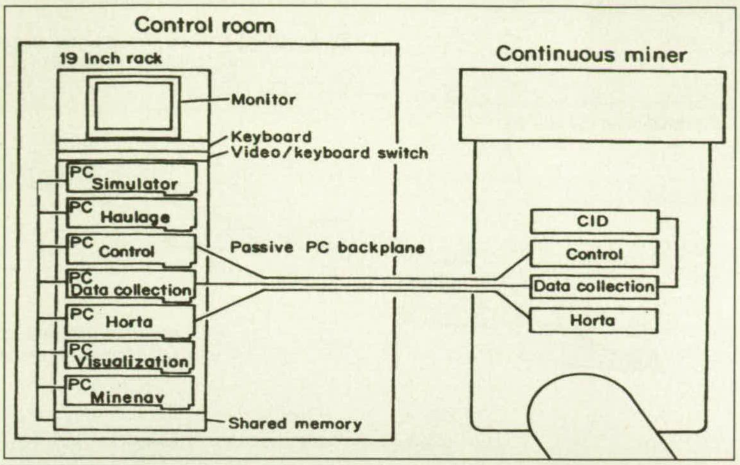
The most important requirement for a computer-assisted mining system is an accurate, reliable navigation system that is mounted on the mining machine to provide the continuous miner's location at all times. The navigation system provides information allowing the machine to cut to a predetermined mine plan. Many different navigation devices were evaluated in an effort to identify the best one for use on the machine. The Honeywell ring laser gyro known as HORTA was selected as the best navigation device for the application. The data provided by the gyro includes position of the machine in state plane coordinates (feet); position of the appendages of the mining machine in state plane coordinates; heading of the mining machine (degrees); pitch, roll, and yaw of the machine (degrees); altitude above sea level, cross-track and along track.

Investigators developed a fieldbus style of control network based on BITBUS standards that allows non-line-of-sight control of all the mining machine's moving parts. The control network consists of a microcontroller board in a 19-in. rack in the control center that attaches to a single-board PC plugged into a passive PC backplane. The two ends of the control network are connected with a twisted cable pair. The network uses a second fieldbus network to provide data collection of the positions of all the moving parts of the mining machine, as well as the status of the machine's critical parameters, such as motor currents, hydraulics, pressures, temperatures, and other relevant parameters. This network consists of sensors, signal conditioning modules, and a microcontroller board on the continuous miner, and a PC card that plugs into a passive PC backplane in the 19-in. rack. The two ends of the data network are connected with a twisted-pair cable. The third connection between the machine and the 19-in. rack is two twisted-pair cables that connect the machine-mounted gyro to a PC

card that is plugged into the PC passive backplane. The controller software is the key element for providing advanced mining operations. By using the data collected from all the continuous miner's sensors and the gyro and by executing commands on the miner, the controller is able to do complete coal-cutting scenarios.

Many modules can and have been added to the design. Each module adds another level of sophistication to the system. Using this method, the technology is capable of adapting to the most primitive or most sophisticated application, simply by adding the modules required for the application. The figure at right shows the system's capabilities. The visualization system uses the collected machine data to provide accurate 3D graphic representation of the mining machine and associated hardware and its movements. Software called Minenav is being developed to provide navigation to the controller computer that will execute a completely orchestrated mining plan from start to finish, using navigation and sensor data. The coal interface detection application (CID) will provide information about the thickness of the coal on the roof and floor, and can also provide information about the thickness of a rib of coal.

This work was done by William H. Schiffbauer of the **National Institute for Occupational Safety and Health**. *For further information, contact Schiffbauer at NIOSH, Pittsburgh Research Center, PO Box 18070, Pittsburgh, PA 15236-0070; (412) 892-6835; E-mail: wcs7@cdc.gov (on Internet).*



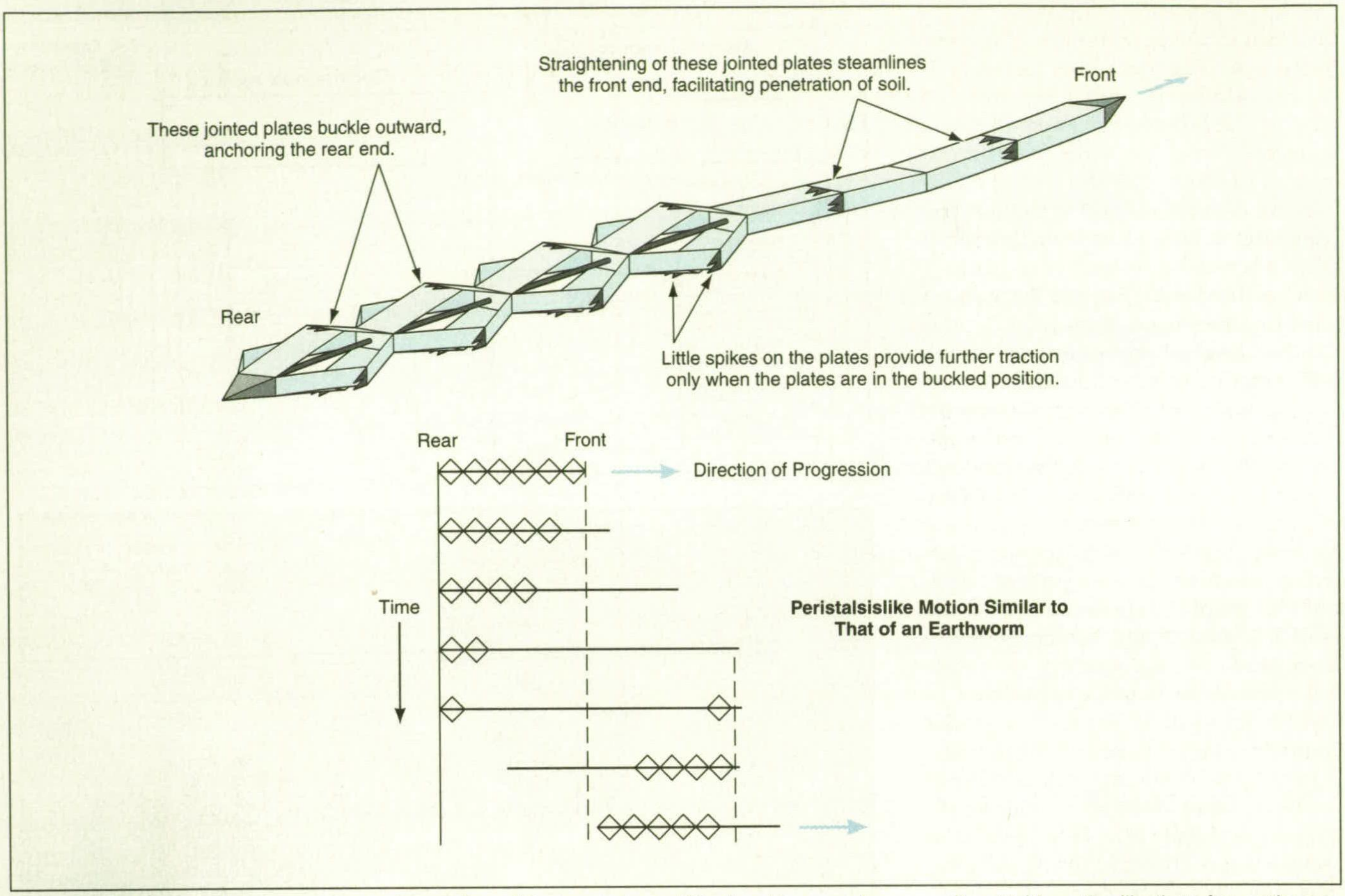
The **Expanded Control System**.

Earthwormlike Exploratory Robots

Mobility would be achieved through coordinated actions resembling peristalsis.

NASA's Jet Propulsion Laboratory, Pasadena, California

Mobile robots that would resemble earthworms have been proposed for use in exploring remote, hostile, or inaccessible terrain surface and subsurface environments. This class of robots would be a special case of a more general class of proposed small, lightweight, relatively inexpensive exploratory robots. Bio-



Shortening/Widening and Elongating/Narrowing motions of the segments would be timed to generate an overall peristaltic motion like that of an earthworm.

morphic explorers would exploit the emerging technology of biomorphic controls and advanced actuators. They would achieve motion by use of simple electronically or photonically controlled, flexible advanced actuators instead of conventional motors with complex drive trains. The robots would carry advanced microsensors for measuring or detecting specific objects or substances. Animallike combinations of mobility, adaptability, fault tolerance and a limited capability for "learning" would be achieved by integrating the actuators with very-large-scale integrated (VLSI) circuits that would implement neural-network and/or genetic algorithms.

The proposed earthwormlike robots would be flexible in the sense that they would be foldable in segments. The first several segments at one or both end(s) of each robot would generate motion. These segments would be covered with hinged plates connected to interior actuators (see figure on page 12b). Upon command, the interior actuator in each segment would shorten or lengthen the segment, causing the plates to buckle outward or to move inward to straighten, respectively. A wave of shortening/buckling versus lengthening/straightening, resembling the peristaltic motion of an earthworm, could be generated by sending coordinated, sequential contraction and expansion commands to the actuators in the segments. By this action, the robot could move along the surface or burrow beneath the surface of terrain. The direction of travel could be reversed by reversing the sequence of buckling and straightening.

Special-purpose microsensors could be housed in one or more end or middle segment(s). The tips on the end segments could be sharpened to facilitate penetration of soil. Alternatively or in addition, the tips could contain sensors and/or mechanisms to collect samples.

The design of the robot, including the details of the mobility features and the choice of sensors, would be specific to the intended application. For example, an earthwormlike robot might be designed to probe earthquake rubble to find missing persons and animals. The sensors for this application could include a miniature active-pixel-sensor video camera, a temperature sensor, and microspectrometer for detecting carbonates, water, and other chemical signs of life.

This work was done by Sarita Thakoor, Kim Quillin, Alex Fukunaga, John Michael Morookian, and Adrian Stoica of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category,* ***or circle no. 138*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). NPO-20266*

Miniature Multispeed Transmissions for Small Motors

Transmissions would be batch-fabricated using micromachining technologies.

NASA's Jet Propulsion Laboratory, Pasadena, California

A design has been developed for manufacturing multispeed transmissions that are small enough to be used with minimotors — electromagnetic motors with power ratings of less than 1 W. Like similar, larger systems, such as those in automobiles, the proposed mechanism could be used to satisfy a wider dynamic range than could be achieved with fixed-ratio gearing.

Free catalogs and literature for *Motion Control Tech Briefs* readers. To order, circle the corresponding number on the Reader Information Request Form (opposite page 88).

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API Harowe Inc.

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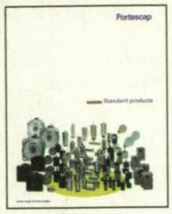

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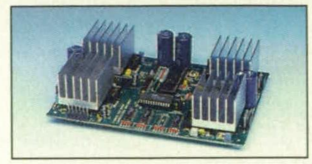

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CUSTOM PRECISION POTENTIOMETERS

Betatronix Custom Precision Potentiometers Catalog provides background on the company's industry-leading design and manufacturing capabilities. Betatronix has manufactured conductive plastic and wirewound potentiometers for 30 years. Catalog covers linear and rotary motion, aerospace and missile, outer space, and robotics and animatronics applications; full-color photos and mechanical parameters of all-inclusive product line are featured. Betatronix, Inc., 110 Nicon Court, Hauppauge, NY 11788; Tel: 516-582-6740; Fax: 516-582-6038; www.betatronix.com

Betatronix, Inc.

For More Information Circle No. 679

1998 MOTION CONTROL CATALOG

Galil's 1998 catalog is 128 pages with specs for ISA, PC/104, VME, and standalone motion controllers with RS-232. Features include: "Mix-and-match" steppers and servos on 1 through 8 axes, memory for application programs, uncommitted I/O, linear and circular interpolation, gearing and Ecam. Also, software for servo tuning and interface to AutoCAD, G-codes and Visual Basic. DOS, Win 3.1, 95 and NT. Catalog includes 28-page technical reference about motion control systems. Galil Motion Control, 203 Ravendale Drive, Mountain View, CA 94043; (650) 967-1700; 800-377-6329; fax (650) 967-1751; web site: www.galilmc.com

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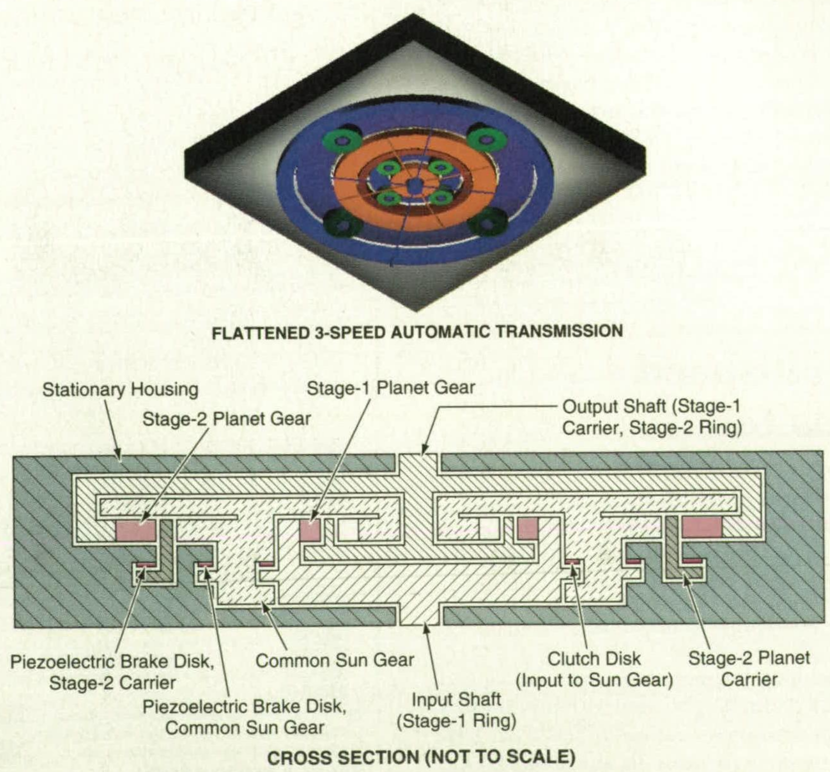


This **Miniature Transmission** could be regarded as a flattened version of a conventional three-speed automatic transmission. The components would be fabricated by micromachining.

However, whereas typical transmission components are machined individually and then assembled, this device would be made using silicon batch-fabrication techniques, similar to those used to manufacture integrated circuits and sensors.

Until now, only fixed-ratio gear trains have been available for minimotors, affording no opportunity to change gears in operation to optimize for varying external conditions, or varying speed, torque, and power requirements. This is because conventional multispeed gear-train geometries and actuation techniques do not lend themselves to cost-effective miniaturization. In recent years, the advent of microelectromechanical systems (MEMS) and of micromachining techniques for making small actuators and gears has created the potential for economical mass production of multispeed transmissions for minimotors. In addition, it should be possible to integrate these mechanisms with sensors, such as tachometers and load cells, as well as circuits, to create integrated silicon systems, which could perform closed-loop speed or torque control under a variety of conditions. In comparison with a conventional motor/transmission assembly, such a package would be smaller and lighter, contain fewer parts, consume less power, and impose less of a computational burden on an external central processing unit (CPU).

Like conventional multispeed transmissions for larger motors, miniature multispeed transmissions would contain gears, clutches, and brakes. However, the designs would be more amenable to micromachining and batch fabrication. Gear stages would be nestled one inside the other (see figure on page 14b), rather than stacked one over the other, creating a more planar device. Actuators and the housing would be fabricated on separate layers. The complex mechanical linkages and bearings used to shift gears in conventional transmissions would not be practical at the small scales of interest here. Promising alternatives might include electrostatic-friction locks or piezoelectric actuators. For example, in the transmission depicted in the figure, piezoelectric clamps would serve as actuators in clutches and brakes.

The structures would be aligned and bonded, followed by a final etch to release the moving parts. The entire fabrication process can be automated, making it both precise and relatively inexpensive. The end product is a "gearbox on a chip," which can be "dropped" onto a compatible motor to make an integrated drive system.

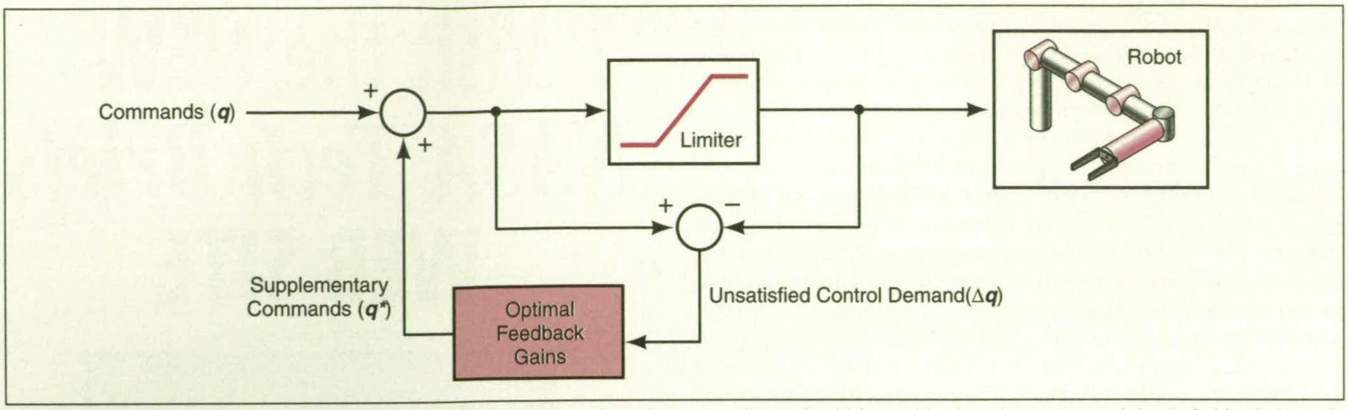
This work was done by Indrani Chakraborty and Linda Miller of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category,* ***or circle no. 139*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). NPO-20316*

A Technique For Compensating Joint Limits in a Robot Manipulator

Upon saturation of a joint, control demand is redistributed among remaining unsaturated joints.

Lewis Research Center, Cleveland, Ohio

A robust, optimal, adaptive technique for compensating rate and position limits in the joints of a six-degree-of-freedom manipulator has been developed. In this new algorithm, the unmet demand as a result of actuator saturation



Robot Joint Commands are used with optimal joint limit compensation. The unmet demand, which would otherwise saturate a joint, is fed back through the optimal gains to provide supplemental commands to joints with authority remaining.

is redistributed among the remaining unsaturated joints. The scheme is used to compensate for inadequate path planning, problems such as joint limiting, joint freezing, or even obstacle avoidance, where a desired position and orientation are not attainable due to an unrealizable joint command. Once a joint encounters a limit, supplemental commands are sent to other joints to best track, according to a selected criterion, the desired trajectory.

A standard six-degree-of-freedom manipulator has six independently controlled joints. The position and orientation of the end effector, each of which is described in three dimensions, are fully determined by the angles of the joints. As long as the appropriate joint angles are achievable, the desired position and orientation can be obtained. However, when the specified joint trajectories cannot be followed due to a command beyond the range of the actuator, positions and orientations downstream from the limited joint will all be affected, causing in some cases extreme deviations from the expected values. This new scheme is an ideal solution candidate for this problem. It was designed to compensate for actuator saturation in a multivariable system by supplementing the commands to the remaining actuators to produce the desired effect on the output, in this case the gripper position and orientation. For each joint which saturates, a degree of freedom is lost, but the remaining joints can be used to track the desired path within the physical limits of the manipulator.

The matrix known as the Jacobian, J, describes how a small change in the joint positions, dq, affects the gripper. The resulting position and orientation change of the end effector, D, is com-

puted as $D = Jdq$. When a joint is commanded to move beyond its limit, a portion of the command cannot be achieved. This unmet demand, Δq, represents the amount the joints should move but cannot. The resulting error in position and orientation of the end effector can be approximated by $D=J\Delta q$. The objective of this new scheme is to duplicate D as closely as possible using joints with authority remaining.

The figure shows the scheme with the optimal gains in the feedback loop. The commands, q, are checked to verify that they will not drive any of the joints to a rate or position limit. Any portion of a command which would cause a joint to saturate corresponds to unmet demand and is truncated and redirected to the feedback gains. The gains take this unmet demand, Δq, and produce some supplemental commands to unsaturated joints, q^*, such that $J\Delta q$ and $J q^*$ are as close as possible. These supplemental commands allow the end effector to optimally track its desired trajectory, even in the face of joint position and rate limits. Since the algorithm acts upon the joint commands only, there is never the possibility of an unstable system resulting from the use of this algorithm.

The optimal feedback gains are computed using a quadratic objective function with task-dependent weights assigned to the components of the position and orientation vector of the end effector. The gains adapt to changes in the Jacobian as the manipulator moves through its workspace, and the computations are robust to singularities arising from particular manipulator configurations. This provides smooth, continuous variation of the optimal gains for as long as Δq is nonzero.

This work was done by Ten-Huei Guo of **Lewis Research Center,** *Jonathan Litt of the Vehicle Technology Center of the U.S. Army Research Laboratory, and André Hickman of Morehouse College. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/ Automation category,* ***or circle no. 140*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16566.

Hybrid Propulsion System for Returning a Sample From Mars

NASA's Jet Propulsion Laboratory, Pasadena, California

A paper suggests the development of a hybrid rocket engine and associated equipment for returning a sample of material from Mars at relatively low cost. In a hybrid rocket engine, a solid fuel is burned by use of a liquid or gaseous oxidizer, the flow of which can be throttled to control the engine. Unlike conventional solid rocket propellants, a solid rocket fuel can be made relatively inert in the absence of the oxidizer and therefore presents little hazard of explosion or inadvertent ignition. Unlike conventional (and relatively expensive) liquid rocket propellants, a solid rocket fuel is not corrosive or susceptible to leakage. The solid fuel in the proposed system would be in granular form, packed into the rocket motor. Oxygen or another suitable oxidizer could be transported from Earth together with this solid fuel. Alternatively, oxygen could be generated from CO_2 in the Martian atmosphere by use of in-situ resource utilization (ISRU) equipment. Inasmuch as ISRU is not yet a mature technological discipline, some research on ISRU would be necessary to estimate the reduction in cost achieved by not having to carry the oxidizer to Mars.

This work was done by Kumar Ramohalli of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the paper, "Hybrids for Low-Cost Sample Return Missions," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category,* ***or circle no. 141*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). NPO-20195*

Hydraulically Driven High-Speed Spindle for General Machining

Improved design for high-speed spindles increases strength and rigidity and improves balance.

Marshall Space Flight Center, Alabama

A hydraulically driven high-speed spindle system for milling, machining, facing, drilling, and joining metallic and nonmetallic materials has been developed. Spindles are the most critical elements of high-speed milling machines. The keys to successful design of high-speed spindles are strength, rigidity, and balance.

The hydraulically driven spindle includes a hydraulically driven gearmotor. The rotation of the motor is transmitted to the main shaft of the spindle. The main shaft supports a fixture that holds the tool to effect the desired operation. The main shaft is supported by a series of bearings that withstand axial and radial loads encountered during use. The pressure and flow rate can be adjusted manually or controlled by a computer. This system includes a hydraulic subsystem that supplies pressurized fluid to drive the spindle.

Pressurized fluid is fed into the

hydraulically driven spindle for machining, milling, drilling, tapping, facing, and joining. Hydraulic fluid volumetric flow rate, fluid pressure, gear size, and geometry of the hydraulic motor are variables which govern spindle torque and rotational speed, ranging from 5,000 to 6,000 rpm and operating at 1,000- to 6,000-psi (6.9- to 4-MPa) pressures.

The bearing system for this hydraulically driven spindle can be made of recently developed fluid bearings or of roller element type bearings. The balls in the bearings in this system can be made of standard steel or of newly-developed ceramics for increased rigidity, accuracy, and longer life. Bearings that are designed for use at lower speeds with air/oil or air/mist lubrication can be used at higher speeds, provided they are lubricated with grease.

High-speed machining allows for the production of thin wall sections with minimal deformation. High-speed machining can make it possible to reduce the number of parts, sometimes even making it possible to fabricate, as unitary parts, objects that would ordinarily have to be assembled from multiple pieces. Therefore, production and assembly times are reduced.

For the purpose of fabricating complex and thin-walled parts, high-speed machining of solid stock can be an alternative to casting and to the more expensive use of composite materials. Use of this hydraulically driven spindle system for high-speed machining reduces times and cost of the manufacturing process and helps to ensure defect-free finished parts.

Another significant advantage of high-speed machining is minimization of effects of heat on machined parts. Most of the cutting heat is removed, reducing thermal warping and increasing the life of the cutting tool. In many cases, the need for a cooling fluid is eliminated. Also, elimination of cutting fluids reduces subsequent contributions to pollution and aids in the recovery and recycling of such expensive materials as aluminum-lithium alloys.

This work was done by Majid K. Babai and Samuel C. Geise of **Marshall Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category,* ***or circle no. 143*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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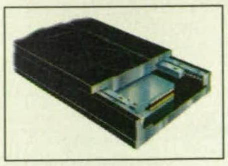
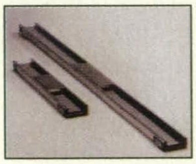


"Plug-and-Play" Motor Slide

MicroSlides Inc., Port Washington, NY, calls its Luge™ a high-performance linear motor slide that offers "plug-and-play" mounting simplicity for almost any off-the-shelf linear motor, including Anorad, Etel, Fanuc, Indramat, Kollmorgen, Normaq, Pratec, Siemens, and Trilogy. They are available for ironless and iron-core motors. For the former, there are two styles: the high-speed model, with travels from 300 to 1500 mm, uses recirculating bearings, and the high-accuracy model, with travels from 250 to 500 mm, uses crossed hollow roller bearings. The iron-core style uses large recirculating bearings, and has travels from 300 to 1500 mm.

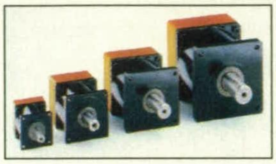
For More Information Circle No. 781



Moving-Magnet Linear Motor

The Lightning Series from Anorad Corp., Hauppauge, NY, is a line of brushless linear DC moving-magnet servo motors that eliminates the requirement for moving power and control cables. Inclusion of an encoder makes the series suitable for applications requiring high velocity (up to 10 m/s), resolution of 5 microns, and repeatability of ±10 microns. A proprietary current-switching technology charges only the coils under the moving magnet, resulting in cool operating temperatures, Anorad says. Applications the company cites include material handling, pick and place, winding machines, flying shear, metrology and dispensing.

For More Information Circle No. 782



Line of Planetary Gearboxes

ITW Spiroid, Glenview, IL, releases a line of planetary gearboxes that it says has more torque, more strength, and more power than conventional involute gearboxes. Available in four frame sizes (300, 1000, 2000, and 4000 series), these gearboxes feature an exclusive CONCURVE® gear design that allows 50 percent more running-time hours at equivalent loads or fifty percent more torque capacity. Backlash is 6 arc minutes standard and minimum efficiency rating is 90 percent for the entire gearbox. All four sizes are available in ratios between 3:1 and 100:1.

For More Information Circle No. 783

Brake Motors in Nine Sizes

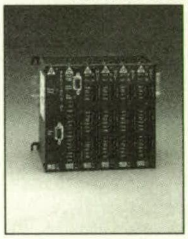
Electroid Co., Springfield, NJ, announces that it offers its EBM Series of brake motors in nine sizes, with horsepower ranges from one-half to 10, and with Power OFF ("failsafe") brake torques from 6 lb. ft. to 55 lb. ft. The company says that the series, combining its AC brakes with a NEMA standard motor, provides reliability and the fastest brake response time in the industry. They are dual wound for 208-230/460 VAC three-phase 60-Hz operation. Recommended applications include machine tools, packaging machinery, conveyor systems, cranes, hoists, and valves.

For More Information Circle No. 784

Rotary Motion into Vacuum

Kurt J. Lesker Co., Clairton, PA, describes its MagiDrive as a device for delivering rotary motion into a vacuum vessel in which the shaft is entirely enclosed by a stainless steel vacuum casing, without O-rings, bellows, or fluids. Between the outer hand-operated or motor-driven rotor and the inner shaft, MagiDrive gives absolute vacuum integrity, since there is no moving seal to fail. Drives of various sizes can be mounted end to end, using conventional copper-gasket-sealed flanges. The device can be heated to 230 °C for ultrahigh vacuum operation.

For More Information Circle No. 785



Servo Motion Controller

Delta Computer Systems Inc., Vancouver, WA, offers the RMC180-Profi, an eight-axis linear servo motion controller. The company says the module provides the power of the Profibus open architecture fieldbus with independent or coordinated control of eight motion axes for precise point-to-point linear positioning. Applications include rolling mill pinch rollers, plastic and ceramic injection molding machinery, die-casting machines, and laser and saw positioning for edgers and resaws. The module is 7 in. wide, 5.8 in. high, and 4 in. deep and weighs 2.75 lb.

For More Information Circle No. 786

Modular Motion Control System

Intelligent Motion Systems, Marlborough, CT, says LYNX™, its modular motion control system, programs easily and interfaces with stepper or digital servo drives. The company adds that the system's 1.5 axes of control makes following external clocks or ratioing a second axis easy for the user. Features include zero to 5-MHz step clock rate, selectable in 0.005-Hz increments through the entire range; and 7 hardware and 62 software addresses for multidrop communication.

For More Information Circle No. 787

Multilingual Variable Frequency Drive

The A500 Series variable frequency drives from Mitsubishi Electric Automation Inc., Vernon Hills, IL, are compact units with ratings of one-half through 100 horsepower at both 240 V and 480 V. All units carry UL and CUL listings and CE marking, and the optional 4-x-13-character back-lit LCD display parameter unit supports users in eight different languages. Mitsubishi says that advanced flux vector control provides superior open-loop torque and speed control, and the optional encoder feedback feature further enhances performance.

For More Information Circle No. 788

Motion Control for 28 Axes

Custom Servo Motors Inc., New Ulm, MN, says that a simple on-line programming system for controlling up to 28 axes makes the Motion Plus™ XDC-720 motion controller ideal for packaging and converting applications. The panel-mounted module features 56 bidirectional I/O points, four high-speed sensor inputs, and two serial ports. The sensors' <1-μs response time makes the XDC 720 useful for product registration and other critical-response applications. Incremental and absolute encoder feedback, analog input, and feedback from the Temposonics® position sensors are accepted by the controller.

For More Information Circle No. 789

Controllers with Pentium MMX

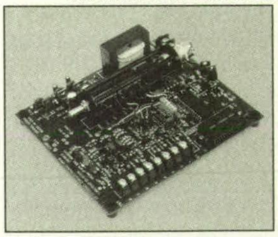
The new ORION® Model 30 motion controllers from ORMEC, Rochester, NY, incorporate the Pentium MMX 233-MHz processor, adding it to the lineup of industry-standard X86-family microprocessors. The new processor offers three to five times more processing power than the fastest ORION processor previously offered. Also offered in the line are the Pentium 133-MHz processor, along with the previously offered 586/133-MHz and 80486 microprocessors. The Model 30 features two PC-card slots, 8 megabytes of RAM, a 512-K external cache, a keyboard connector, and three 16-bit ISA-bus expansion slots.

For More Information Circle No. 790

Controller with Three Indexers

Continuum Engineering Inc., Tarzana, CA, announces availability of the second generation of its MCL Series multiaxis controllers. The MCL-300 motor indexer/driver is described by the company as a complete turnkey solution because it combines the function of three indexers, three drivers, and a power supply in one package. Single- and double-axis versions are also available. Features include internal fused and filtered power supplies for all drivers and control logic, CW/CCW limit and home optically isolated switch inputs, and a three-axis joystick with multiple speed settings and LED indicators.

For More Information Circle No. 791

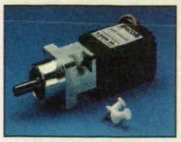


Driver Board for Position Control

The Series 6500 from ETI Systems Inc., Carlsbad, CA, is a self-contained driver system for motorized potentiometers, and operates as an analog control interface. It uses a dual-gang potentiometer to provide an isolated variable output and feedback to null the servo system at the desired position. The 6500 accepts inputs of 0-10 VDC, or 4-20 mA, or 16-bit binary signals. The company says average accuracy exceeds 0.2 percent. An inhibit control eliminates uncommanded movement.

For More Information Circle No. 792

New Products



Zero-Backlash Gearmotor

The 535MBG cycloidal gearmotors from Nyden Corp., San Jose, CA, are NEMA 17 size and have zero backlash. They feature positional accuracy of less than ±60 arc sec., efficiency of 85 to 90%, low audible noise, and long mechanical life. The gearmotors integrate a five-phase stepping motor with an in-line cycloidal ball reducer that increases output torque and output precision. Standard reduction ratios of 5:1 and 10:1 offer 10,000 and 20,000 steps of true resolution per one revolution of the reducer's output shaft at up to 108 oz in. of torque. Applications include linear and rotary table positioning, robotic arm actuation, and index feed mechanisms.

For More Information Circle No. 748

Step Motor System

The CMAX-810 microstep control system from Advanced Micro Systems, Nashua, NH, is rated for 8 amps at 80 volts or 160 volts. The unit incorporates the company's Variable Resolution Microstep Control (VRMC®) indexing technology with high-output, bi-polar chopper drives and toroidal power supplies. Packaged in a compact, heat-sinked, and fan-cooled enclosure, the unit provides serial communication, 2K bytes of non-volatile memory, extended industrial I/O, and AC power entry. Other features include integral controller/driver/power supply; power line filtering and surge protection; and short circuit, over temperature, and under voltage protection.

For More Information Circle No. 757

Servo Class Couplings in Large Sizes

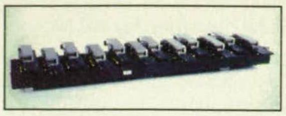
Zero-Max, Minneapolis, MN, has introduced Servo Class couplings in eight sizes in torque ranges from 8.84 to 880 in lbs. for servomotor and precision motion control applications. The couplings feature zero-backlash, flexible metal discs, and keyless clamp-type mounting hubs. They offer high torsional stiffness and low inertia, and accommodate higher torque, high speed, and high misalignment. Other features include one-piece assembly, lightweight design, and maximum RPM of 10,000.

For More Information Circle No. 761

Accelerometer Offers High Sensitivity

The Model 370A03 capacitive accelerometer from PCB Piezotronics, Depew, NY, features 1000 mV/g sensitivity (±5%) for high-resolution measurement of sensitive vibration events. Operating from a standard 16 to 28 VDC power supply, the hermetically sealed accelerometer provides a lower noise floor, allowing the user to measure very low-level vibration. The unit takes measurements in any orientation, drives long cables, and handles frequencies from pure DC to 100 Hz (±5%). Air damping improves temperature stability and allows the device to withstand higher-g overloads.

For More Information Circle No. 764



24-Axis Positioning Stage

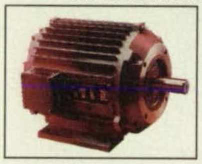
Northern Magnetics, Santa Clarita, CA, has released a 24-axis linear motor-driven positioning stage that provides independent motion along all 24 axes, as well as rapid acceleration and deceleration. The base stage is a 72-inch-long single (X) axis EPS positioning stage with a non-cogging, medium-force brushless linear motor with 12 independent coil assemblies. Each assembly has a 1-1/2" stroke, bellows, encoder, special bearings, and limit switches. Mounted to each X-axis slide is a single (Y) axis special bearing positioning stage with a non-cogging, medium-force brushless linear motor with 3.5" stroke, encoder, and limit switches.

For More Information Circle No. 749

Miniature and Compact Load Cells

The EL Series miniature and compact load cells from Entran Devices, Fairfield, NJ, measure compression and/or tension, and are available in 15 styles and shapes for a range of applications. Compact to robust, or low-profile to threaded models are available in either English or metric threads. Full-scale load ranges are available from 1 pound through 20,000 pounds; 5 Newton through 10,000 Newton; and precision low ranges to 20 grms or 0.2 N. Applications include force and weight measurements in industrial, automotive, aerospace, and biomechanic labs and factory installations.

For More Information Circle No. 760



AC Synchronous Motors

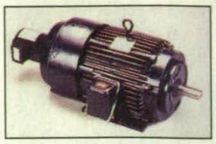
VARI-HERTZ® 1/4- to 10-horsepower permanent magnet AC synchronous motors from Welco Technologies, Milford, OH, are designed for applications requiring precise open-loop speed control for constantly fluctuating temperature and load conditions. The motors simplify synchronization of two or more pieces of equipment by eliminating the need for external feedback devices such as resolvers or encoders. Available features include 2 through 12 pole designs, TENV or TEFC enclosures, and speeds up to 18,000 RPM. The motor design allows it to operate in a precise ratio to the frequency being sent to the motor by the variable speed drive.

For More Information Circle No. 762

Controller Offers Fieldbus Conductivity

Parker Hannifin Corp., Compumotor Division, Rohnert Park, CA, offers the Compax servo controller, which features Fieldbus conductivity options. The position, velocity, and torque controller is used with three-phase sinusoidal brushless motors, and offers speeds up to 5,000 RPM and shaft power up to 15 Kw. The controller features a dual microprocessor design in which the host processor handles I/O and low-speed communications, and a DSP controls the digital current loop and processes encoder and resolver data. The unit is available in both single-axis and multi-axis configurations.

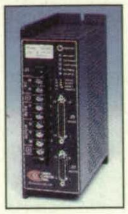
For More Information Circle No. 765



Torque Motors for AC Drives

Danfoss Electronic Drives, Division of Danfoss, Rockford, IL, has introduced the Blue Max® and Black Max® line of variable and constant torque motors with a range of horsepower from 1 to 350 HP. The Blue Max AC inverter duty motors feature a variable torque XRI motor designed for optimum torque operation in pump and fan applications. The Black Max family features an aluminum frame motor that provides constant torque with a 1000:1 speed range.

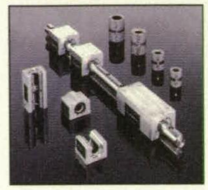
For More Information Circle No. 759



Servoamplifier for AC Motors

The Model 7425AC from Copley Controls Corp., Westwood, MA, is a servoamplifier for driving AC brushless motors in the torque mode. Operating directly from 50/60-Hz power supplies, the amplifier develops symmetrical sinusoidal output waveforms for energizing the motor's three U, V, and W stator coils, synthesizing the third (W) waveform from the U and V current commands provided by the controllers. The amp can drive AC brushless motors to 2.5 hp.

For More Information Circle No. 779



Bearings with Added Travel Life

Thomson Industries Inc., Port Washington, NY, introduces the JIS (Japanese Industrial Standard) Metric Super Smart Ball Bushing™ linear bearings and pillow blocks. The company says these bearings provide 6X the load capacity, or 216X the travel life, of conventional JIS bearings, and are universally self-aligning for easy low-cost installation. Available in16-mm to 40-mm sizes, the bearings are dimensionally interchangeable with conventional JIS bearings and pillow blocks. Thomson says the quantum increase in load capacity enables a 90-percent cost reduction with downsizing.

For More Information Circle No. 780

Microdrive with Quick Response

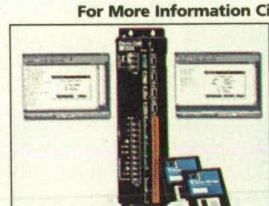
ABB Industrial Systems Inc., New Berlin, WI, says its new ACS 140 is the world's fastest microdrive. Capable of responding to input signal changes in as little as 9 milliseconds, it is available in a variety of frame sizes ranging from one-half to 3 HP, 230 VAC and 460 VAC, in single- and three-phase configurations. Seven application macros permit users to select a preset pattern of parameter values and I/O configurations, and the user can also tailor them to suit. There are three options for installation: wall mounting, DIN-rail mounting, or flange mounting.

For More Information Circle No. 804

Modular Controller System

Melles Griot, Boulder, CO, introduces a main rack and controller PC, which can be bench-cabinet or 19-inch-rack mounted, and can drive up to 32 module racks to accommodate system expansion or extremely complex applications. The main suite of modular control software resides in the controller unit, and offers four control options: Visual Basic, C, LabVIEW, and Melles Griot Macro Environment, running under Windows NT or Windows 95. Available drive modules include piezo actuators, stepper motor drivers, and, for precise nanometric auto-alignment, a NanoTrak™ driver.

For More Information Circle No. 805



Servo Drives with Electronic Camming

Electro-Craft Division of Rockwell Automation, Eden Prairie, MN, announces the addition of camming capability to its Electro-Craft® IQ-Series® positioning servo drives. The programmable IQ Cam enables replacement of mechanical cams with electronic servo-based systems that can be modified to accommodate different product lengths and cam profiles. Integrated programmable limit switch capability provides commands to activate designated outputs at defined machine positions. The IQ-Series is available in power output ranges from 1 to 15 kW.

For More Information Circle No. 806

Wavelet Processing for Aeroservoelastic-Stability Analysis

Stability margins are more realistic and robust than those obtained by older techniques.

Dryden Flight Research Center, Edwards, California

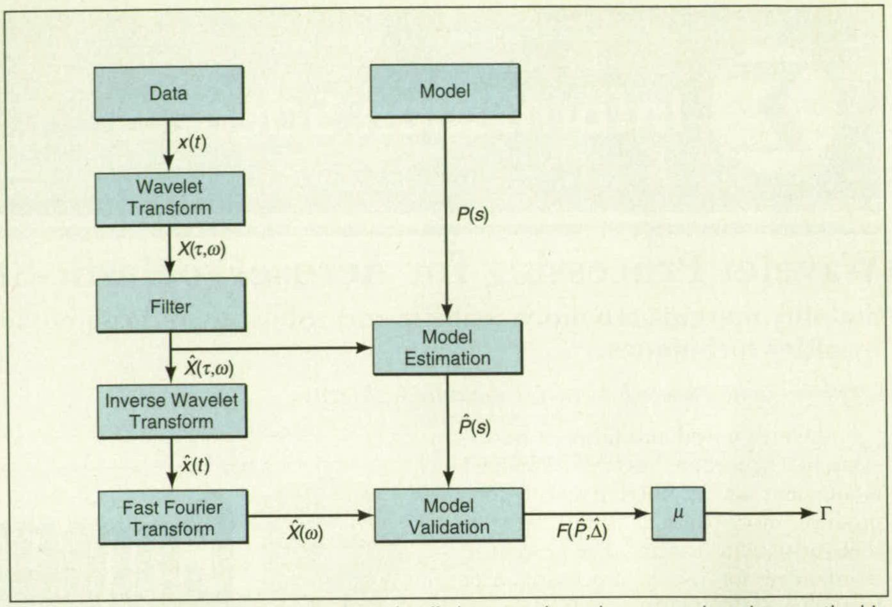
A wavelet-based modal-parameter-extraction procedure has been developed to augment wavelet filtering and thereby produce more-realistic, robust aeroservoelastic-stability margins. The procedure is intended for use in processing data from aircraft flight tests.

Some background information is prerequisite to an explanation of this development. Deterministic nonstationary input test signals are often essential for extracting aeroelastic-stability trends from noisy measurements. The analysis of flight data is improved by discrimination among areas of low signal-to-noise ratio, unmodeled dynamics, and external disturbances. Wavelet signal processing has shown promise for identification of the conceptual structures, operators, and parameters of mathematical models (hereafter called "system identification") of aeroservoelastic systems for these purposes.

Nonparametric wavelet filtering removes aspects of signal responses detrimental to linear system-identification methods to improve stability tracking. Wavelet transforms are also used to directly supply information on time-dependent modal decay rates and phases for estimation of parameters of mathematical models of time-varying systems. Without any approximation of the range of parameters of a system, natural frequencies and damping ratios are extracted from the response of the system. Damping and frequency trends are useful for noting changes in system dynamics as functions of flight conditions.

Model validation is a critical procedure in the computation of robust stability margins. The margins are adversely affected by poor characterizations of uncertainty size and structure, which are determined by the magnitudes of perturbations, locations of perturbations within the system, and the types (real or complex) of perturbations. This completes the background information.

In the present wavelet-based modal-parameter-extraction procedure, both complex, nonparametric and real, parametric perturbations are decreased to generate reduced-norm uncertainty sets,



The **Flows of Information** represented graphically here are those that occur when the μ method is coupled with wavelet processing for robust stability-margin analysis of an aeroservoelastic system.

which result in models with less conservatism. The models are used in a robust stability-boundary-prediction method called the "μ method" because it is based on a structured singular value called "μ." [This method was described in "Characterizing Worst-Case Flutter Margins From Flight Data" (DRC-97-03), *NASA Tech Briefs,* Vol. 21, No. 4 (April 1997), page 62.]

Within the μ conceptual framework, a system is represented as an operator, $F(P,\Delta)$, which, in turn, represents a feedback interconnection of a plant P and uncertainty Δ. Flight data can be incorporated into the μ method by formulating a description of uncertainty that accounts for observed variations and errors. A model-validation analysis is performed on the plant model to ensure that the range of dynamics admitted by the uncertainty is sufficient to cover the range of dynamics observed with the flight data.

The μ method can be coupled with wavelet processing for parametric and nonparametric estimation. This coupling is achieved by introducing, into the basic process, several time-frequency operations based on wavelet filtering (see figure). Wavelet transform operations are introduced to process time-domain data, $x(t)$, before computation of a frequency-domain representation, $\hat{X}(\omega)$. These operations map the time-domain data into the time-frequency domain via a wavelet transform, then map them back to the time domain via an inverse wavelet transform. A time-frequency filtering operation is performed between the wavelet transform and the inverse wavelet transform to remove unwanted features before the inverse wavelet transform yields a time-domain signal, $\hat{x}(t)$.

A modal-parameter-estimation algorithm is introduced by use of the wavelet algorithm. The estimated parameters are used to update the elements of a nominal plant model, P, and a new plant model, $\hat{P}$, is used to represent the dynamics of the aeroservoelastic system.

The final operations of the μ method are traditional robust-stability operations on frequency-domain data. The effect of the wavelet filtering is to introduce filtered versions of the data and the plant model for model validation. Thus, a new uncertainty operator, $\hat{\Delta}$, is associated with the parameter-updated plant, $\hat{P}$, to account for errors observed from the filtered data, $\hat{x}(t)$. There is computed a robust stability margin, Γ, that describes the largest change in dynamic pressure for which $\hat{P}$ is robustly stable to the errors, $\hat{\Delta}$.

Nominal stability margins are computed for the plant model by use of the original theoretical modal parameters and are computed for the updated model by use of parameters estimated from wavelet filtering. These margins are computed from a μ analysis with respect to variation in dynamic pressure, $\bar{q}$, but ignoring the modal and complex uncertainty operators.

This work was done by Martin J. Brenner of **Dryden Flight Research Center** *and Rick Lind of NRC. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category,* ***or circle no. 175*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
DRC-98-26

Books & Reports

Micromachined Tunneling Accelerometer for Use in Outer Space

Two short reports describe a micromachined quantum-mechanical-tunneling accelerometer and radiation-hardened support electronics designed for use in outer space. Like the micromachined tunneling accelerometers described previously in *NASA Tech Briefs,* this device is based on the use of electronic sensing/feedback control circuitry that measures acceleration in terms of an electrostatic-deflection voltage necessary to maintain a small constant distance (typically a few Angstroms) between a membrane and a tunneling tip in a mechanical acceleration-sensing/electron-tunneling device.

This work was done by Vardkes Victor Boyadzhyan-Sevak of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain copies of the reports, "ATC Electron Tunneling Accelerometer Integrated Sensor Circuitry for Space Applications" and "Tunneling Accelerometer Multichip Module (Integrated Sensor) Thin Film Technology Radiation Hardened MCM," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Compoments and Circuits category,* ***or circle no. 188*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Technology Reporting Office
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(818) 354-2240

Refer to NPO-20013, volume and number of this NASA Tech Briefs *issue, and the page number.*

Solar/Infrared Aerobots for Exploring Several Planets

A report discusses a class of balloon-borne robotic instrumentation systems that have been proposed for use in exploring Venus, Jupiter, Saturn, Uranus, and Neptune. The balloons would be of the Montgolfier type; that is, buoyancy would be achieved through heating of atmospheric gases contained in the balloons at ambient pressures. However, unlike the familiar fire-heated hot-air balloons invented by the Montgolfier brothers, the proposed balloons would be heated primarily by the Sun during the day and by infrared radiation from relatively warm planetary surfaces at night. The proposed balloons would be modified versions of solar/infrared-heated Montgolfier balloons that were flown in the upper stratosphere of the Earth by the French space agency CNES during the 1980s. The lower parts of those balloons were made of infrared-transparent polymeric materials to admit infrared radiation from below, the upper inside surfaces were blackened to maximize absorption of the admitted infrared radiation, and the upper outside surfaces were aluminized to minimize radiation of heat to outer space. During the day, the balloons would rise high due to solar heating. At night, the balloons would sink lower, with the descent slowed by heating due to compression of the contained gasses, as well as by heating from lower planetary radiation.

This work was done by Jack Jones, Matthew Heun, and Kerry Nock of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Solar Infrared Balloons for Venus, Jupiter, Saturn, Uranus, and Neptune," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 184*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20264

Analysis of Stresses and Deflections in RTDs

A report presents an analysis of stresses and deflections in resistance temperature detectors (RTDs) of various model numbers with standard sizes and shapes. The RTDs are assumed to be installed in pipes that contain flows of oxygen and hydrogen in a test facility at Stennis Space Center. The analysis, performed in a spreadsheet format, involves calculation of maximum stresses and deflections for each RTD under specific fluid conditions. The drag force is entered as a circular reference in the spreadsheet and must be calculated iteratively. The equation for drag force is used to calculate the allowable fluid density for a given velocity. The deflection of the RTD at the inner pipe wall is also compared with the

maximum allowable deflection at that point. The output of the analysis is a curve, for each RTD model and size, of fluid density versus flow speed. On the basis of allowable stress and deflection, it is deemed to be safe to operate an RTD at any point below its curve. Thus, the collection of curves serves as a guide for preliminary selection of RTDs for the facility.

This work was done by Michael Jee of Lockheed Martin for **Stennis Space Center.** *To obtain a copy of the report, "RTD Stress Analysis for the E-1 Test Facility," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 198*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
SSC-00064

Performance of a Soft Digital-Data-Transition Tracking Loop

A report discusses the performance of a soft digital-data-transition tracking loop (DTTL) in a radio receiver that recovers digital data conveyed by binary phase-shift keying. The DTTL is used as a symbol synchronizer; it provides symbol timing to essential parts of the receiver. The DTTL includes a quadrature channel and an in-phase channel, which contains a transition detector with a hyperbolic-tangent response. The DTTL is said to be "hard" or "soft" in the special case of high or low signal-to-noise ratio (high or low SNR, respectively), for which the hyperbolic tangent can be approximated as a hard-limiting or a linear function, respectively.

This work was done by Samson Million and Sami Hinedi of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Tracking Performance of the Soft Digital Data Transition Tracking Loop," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category,* ***or circle no. 172*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20154

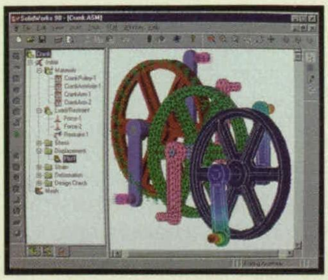
Muscle Wires for Planetary-Exploration Robots

A report proposes the use of muscle wires as mechanical actuators for planetary-exploration robots. Muscle wires are commercially available in kit form in the hobby market, and have been described (though not explicitly called "muscle wires") in previous articles in *NASA Tech Briefs*. A muscle wire is made of a shape-memory alloy. By sending a sufficient electric current along the wire, one can heat the wire above its transition temperature, causing it to change length. When the current is turned off, the wire cools, returning to its original length. The aspects of muscle wires that make them attractive for planetary-exploration robots are low mass, simplicity, and the ability to exert large tensile forces (thousands of times their own weights); in these aspects, muscle wires are superior to conventional electric motors. Moreover, because of their low thermal masses, muscle wires would respond to turn-on and turn-off of currents rapidly enough for the actuation frequencies needed in planetary-exploration robots.

This work was done by Kumar Ramohalli of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Muscle Wires for Efficient Planetary Exploration Robots," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 111*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20194

New on DISK

Visualization/Analysis



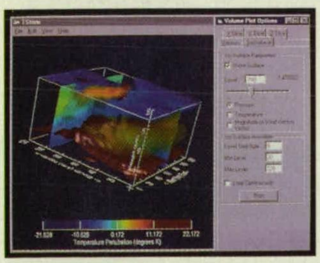
Structural Research & Analysis Corp., Los Angeles, CA, offers COSMOS/Works 4.0 for SolidWorks 98 that allows design engineers to analyze complete SolidWorks assemblies with a new Assembly Analysis module that can be added to COSMOS/Works Basic for $1,500. COSMOS/Works 4.0 is fully integrated into SolidWorks and allows design-team members to communicate design information through reports reviewed and distributed via the Internet. Intelligent application of loads and boundary conditions enables the program to identify the model geometry, automatically applying the appropriate loads and boundary conditions. Other features include drag-and-drop of material properties and results settings. **Circle No. 717**

Electromagnetic Design

OPERA Version 7 for analysis of electromagnetic design is offered by Vector Fields, Aurora, IL. New features include automatic mesh generation in both 2D and 3D; a new 3D analysis module for rotating machines; full anisotropic material definitions; and a user-friendly interface. Modules are available to analyze static, magnetic and electric fields, time varying (eddy current) effects, rotating machine models in 3D, eddy currents due to velocity effects, particle beam optics with space charge limitations, and high-frequency devices such as resonant cavities. The software is available for various platforms, including PCs and workstations. **Circle No. 725**

Interactive Data Language

IDL Version 5.1 from Research Systems, Boulder, CO, offers support for Microsoft's ActiveX Component Object Model (COM) architecture, allowing users to integrate IDL capabilities such as advanced graphics and data analysis with COM-enabled development environments such as Visual Basic, Visual C++, and Delphi. Data analysis and visualization capabilities can be added to COM-enabled programs such as Excel and other Windows productivity applications. Additional features include native clipboard support; enhanced TrueType font support; Basic Linear Algebra Subroutines (BLAS) for rapid processing of large multi-dimensional arrays; and performance-tuned statistics routines with improved user interfaces. IDL 5.1 is available for Windows 95/NT, Mac OS, UNIX, LINUX, and OpenVMS. **Circle No. 718**

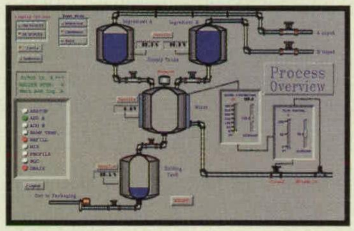


Data Analysis Tools

The MathWorks, Natick, MA, has announced the availability of MATLAB 5.2, an application-development platform for analyzing data, building models, prototyping solutions, and developing custom end-user software. Also released were MATLAB 5-compatible versions of the MATLAB Compiler and C/C++ Math Libraries, enabling users to develop large-scale applications in MATLAB while preserving existing investments in programs written in C and C++. MATLAB code, data, and graphics are transferable across platforms. The new version has expanded data manipulation features, increased control over visualization tasks, and new capabilities in application-specific Toolbox add-ons. It is available for Windows 95/NT, UNIX, and Macintosh platforms. **Circle No. 719**

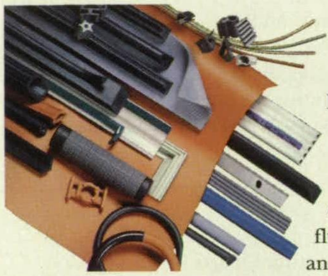
Real-Time Data Display

Sammi Format Editor Plus (FE+) from Kinesix Corp., Houston, TX, unites two core components of the Sammi Application Development Kit (ADK) to create graphical, interactive displays of real-time data. The software gives Sammi users the ability to create functional interfaces and connect them to sources that simulate actual data updates. FE+ combines the look and feel of a PC drawing program with the functionality of a full-featured CAD product. Users can "drag-and-drop" more than 40 pre-built static objects and dynamic building blocks. The program is available for Windows NT and UNIX platforms. **Circle No. 720**



New on the MARKET

Polymer Seals and Gaskets



Lauren Manufacturing, New Philadelphia, OH, offers Super Seal, a line of high-performance extruded polymer seals and gaskets made from silicone, fluoroelastomer-coated polymers, and fluoro-elastomers. The silicone seals and gaskets retain rubbery properties through temperature extremes. They can be compounded to perform for extended periods at 150°F to 500°F. Seals and gaskets coated with a thin film of fluoroelastomer polymer protect the substrate from oil, fuels, acids, and solvents. Fluoroelastomer seals and gaskets also provide resistance to oils, fuels, acids, and solvents at elevated temperatures. **Circle No. 702**

Sealed Linear Actuator

EXLAR Corp., Chanhassen, MN, has introduced the GS Series of electric, compact, sealed linear actuators that combine a brushless servo motor as the driving force, with an inverted roller screw mechanism as the power transmission. With the electronic feedback source, the package is the same size as a typical brushless motor. The actuators provide continuous thrust ratings from 100 to 8000 pounds and speeds to 40 in/sec. Frame sizes range from 2 to 6 inches. The roller screw mechanism provides lead accuracy of 0.001 in/lin. ft.; zero backlash units are available. The actuators are available in a variety of stroke lengths, sizes, speeds, and mounting configurations. Custom designs are available. **Circle No. 704**

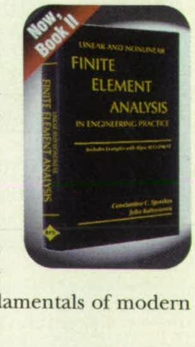
Portable Data Acquisition System

IOtech, Cleveland, OH, has introduced the WaveBook/516™ portable data acquisition system, which uses a DSP-based A/D design to achieve up to 1-MHz sample speed while maintaining 16-bit resolution. The PC-based, multichannel system combines high resolution and high speed in a portable notebook-sized form factor. The eight-channel system can be expanded to sample up to 72 channels of voltage, acoustic, vibration, strain, temperature, and other transducer input. Operable from AC or DC power, the unit connects to a notebook PC via an enhanced parallel port or an optional PC-Card interface. Other features include low-noise architecture, advanced triggering, pre- and post-trigger, external clock, channel and range scanning, signal connections, WaveView™ Out-of-the-Box™ software, and expansion options. **Circle No. 708**

Mini Pressure Transducer

The Model 355 subminiature pressure transducer from Sensotec, Columbus, OH, is a one-piece, stainless steel unit that features a flush diaphragm design for operations involving spraying or application of coatings, sealants, paints, or other congealable media. The transducer accepts input voltage from 9-32 VDC and provides output of 4-20 mA or 0-5 VDC output. The Model 355 is available in pressure ranges from 0-500 psi through 0-5,000 psi. Operating temperature is from -40°F to 200°F, with a standard compensated temperature range from 60 to 160°F. The unit measures 2.5" in length and has a 7/16"-20 UNF straight-thread pressure port. It is welded and hermetically sealed. **Circle No. 714**

Nonlinear FEA Book

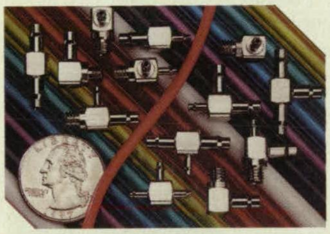


Linear and Nonlinear Finite Element Analysis in Engineering Practice by Dr. Constantine Spyrakos, is available from Algor, Pittsburgh, PA. The book seeks to simplify the topic of nonlinear finite element analysis (FEA), making FEA a practical tool for mechanical engineers. The book provides information on topics such as breaking, buckling, bouncing, shattering, swinging, rotating, and oscillating. It is the second in a series of books by the professor. The first book, *Finite Element Modeling in Engineering Practice*, explains the fundamentals of modern engineering analysis. **Circle No. 709**

Clamp-On Ammeter

The HHM51-DC digital clamp-on DC ammeter from OMEGA Engineering, Stamford, CT, measures DC current up to 1200 ADC, DC voltage to 200 VDC, and resistance to 2000 Ohms. It is designed for

checking equipment such as dc motors, starters, generators, and voltage regulators. No connections are necessary when measuring current since the inductive pick-up clamps around any single conductor. Standard features include high-contrast LCD readout, display hold, and amp zero adjustment. It comes with an integral clamp-on jaw for DC current measurement, contact probes for DC voltage and resistance measurements, a carrying case, and battery. **Circle No. 701**



Slip-On Fittings

Clippard Instrument Laboratory, Cincinnati, OH, has introduced Minimatic® Slip-on Fittings as an alternative to ferrule and push-to-connect design fittings. They feature a single-barb design that provides a slip-on/locked-on connection, and are available in multiple configurations with 1/16" or 1/8" hose barb, and ported #10-32 or 1/8 NPT. The low-profile fittings are designed to be used with flexible Clippard urethane hose. The leak-free connection will hold to the burst pressure of the hose without the need for additional clamps. Electroless nickel plating offers corrosion resistance. **Circle No. 703**

Pocket-Sized Infrared Thermometers

Three pocket-sized, non-contact infrared thermometers are available from Yokogawa Corporation of America, Newnan, GA, for temperature measurement of electrical equipment such as transformers, motors, circuit breakers, bus bars, and HVAC systems. They safely measure temperatures to 752°F in one second with the push of a button, and are accurate to ±1% of reading. The model 530 01 is for general-purpose measurements with a distance-to-target ratio of 10:1. The model 530 03 is for small objects and analog output, and the 530 04 measures small targets down to 35 mm at a distance of 1 meter with laser sighting. All models are switchable from degrees F to C, dark to bright emissivity, and max/hold mode. **Circle No. 710**

Two-Channel Signal Analyzer

Stanford Research Systems, Sunnyvale, CA, has introduced the SR785 two-channel dynamic signal analyzer that features Analog Devices' ADSP21020 32-bit floating point processor, which allows the system to deliver a two-channel 100-kHz real-time bandwidth. A low-distortion source generates sine, two-tone, white noise, pink noise, burst, chirp, and arbitrary waveform outputs. Basic measurements include FFT, order tracking, real-time octave analysis, correlation, and time capture mode. Using two 16-bit ADCs, all single and two-channel measurements can be made on spans up to 102.4 kHz. Other features include a 1.44-MB DOS-compatible 3.5" floppy drive; GPIB and RS-232 computer interfaces; and a printer port. **Circle No. 712**

Image/X-Ray Analyzer

AutoSEM 1 is a PC-based image and x-ray analyzer from Advanced Research Instruments Corp., Boulder, CO, that works with virtually any scanning electron microscope (SEM). It produces particle/feature and field data such as area, size distribution, number of features per field, and percent area coverage, and performs x-ray analysis on each feature. It can operate live or automatically without operator attendance. The system provides complete image/x-ray analysis reports, including statistics in standard spread-sheet format; digital color-coded x-ray maps based on composition; digital high-resolution imaging; image enhancement; image archiving; and printed images. **Circle No. 705**

Precision Screws

Allied Devices, Baldwin, NY, has introduced AccuStar™ Phillips-head precision shoulder screws for close tolerance applications. The screws are engineered with high precision tolerances in shoulder diameter, shoulder length, and concentricity of thread to shoulder. The Phillips head provides torque control and is suited for automatic insertion or robotic assembly. The AccuStar™ screws are manufactured in magnetic and non-magnetic 303 stainless steel, in standard and custom sizes. **Circle No. 700**

New LITERATURE

Digital Panel Meters

The 1998 Acculex Catalog and Reference Guide from Keithley Instruments, Cleveland, OH, highlights Acculex digital panel meters, panel printers, and associated instruments. New products include the DP-899 Process Indicator Alarm that allows user selection of high and low setpoints; the Big Digit Temperature Meters for direct temperature measurements; and the DP-7000 Series six-digit LCD display counters, timers, and ratemeters. **Circle No. 730**

Adhesive Tapes

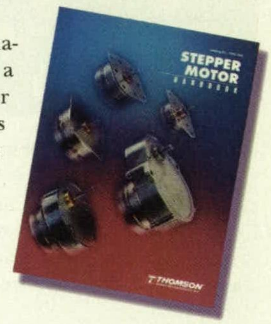
The FT 8306, FT 8326, and FT 8708 adhesive tapes are described, with applications, in literature from Avery Dennison, Specialty Tape Division, Painesville, OH. The FT 8306 is a double-coated film, permanent/removable differential adhesive tape; the FT 8326 is a permanent/permanent tape; and the FT 8708 is a pressure-sensitive adhesive fastening tape for bonding two substrates together. **Circle No. 732**

Vacuum Metallizing

Metallized Products, Winchester, MA, has released a brochure describing products and services incorporating vacuum metallizing technology. Capabilities include UV/EB cured products, vacuum metallizing, and thermal laminations. Products available include multi-ply laminates, superinsulation, crosslinking, functional coatings, and decorative coatings. **Circle No. 728**

Stepper Motors

Thomson Industries, Airpax Mechatronics, Port Washington, NY, offers a handbook of permanent magnet stepper motors and geared motors. The motors range from 15 to 60 mm in diameter; provide step angles of 1.8 and 3.6° (hybrids) and 3.6, 7.5, 15, and 18° (permanent magnet); come in industry-standard configurations; and are available in a range of magnet materials. **Circle No. 729**

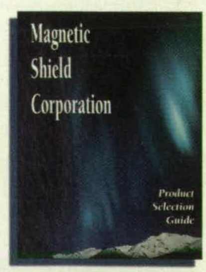


Engineering Design Guide

Switchcraft, Chicago, IL, offers a 350-page engineering design guide that features more than 5,000 electronic and electromechanical components from five product categories: connectors, jacks and plugs, jack panels and jackfields, molded cable assemblies and patch cords, and switches. Specifications, part numbering systems, mating, and ordering information are provided. **Circle No. 731**

Magnetic Shielding

Magnetic Shield Corp., Bensenville, IL, has released a six-page brochure of magnetic shielding products and materials for transformers, CRTs, motors, relays, and other components. Included are enclosures, vacuum shields, zero gauss chambers, magnetic field evaluator probes, and materials such as stock alloys and annealed foils. **Circle No. 734**



Test & Measurement

A 1998 catalog of test and measurement equipment from Marconi Instruments, Fort Worth, TX, features test solutions for RF and microwave products. An updated selection of signal sources, radio test sets, and microwave and RF analyzers is included. **Circle No. 727**

Vol. 22, No. 6 June 1998 This card expires: November 30, 1998

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269	270	271	272	273	274	275	276	277	278	279	280	281	282
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LITERATURE SPOTLIGHT

1998 INSTRUMENTATION CATALOG

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National Instruments

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AIRSTROKE®, AIRMOUNT® ENGINEERING MANUAL & DESIGN GUIDE

Firestone Industrial Products Company offers a revised version of its Engineering Manual and Design Guide for Airstroke® actuators and Airmount® isolators. The free manual provides updated guidelines and specs for the air springs, including height, force, and stroke data. Also included are examples of typical isolation and actuation problems that can be solved by using air springs. Firestone Industrial Products Co., 12650 Hamilton Crossing Blvd., Carmel, IN 46032; Tel: 800-888-0650; www.firestoneindustrial.com

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EXAIR Corporation

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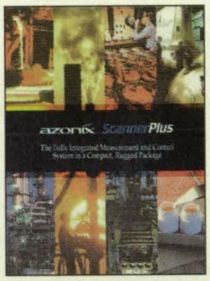

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NEW INSTRUMENTS & DATA ACQUISITION CATALOG

The new Keithley 1998 catalog is available in print or on CD. It features a wide range of instruments and data acquisition products, including DMMs, electrometers, precision sources, voltmeters, picoammeters, ohmmeters, source-measure units, power supplies, switch systems, and semiconductor characterization systems, plus PCI, ISA, PCMCIA, and IEEE bus boards with an array of software to complete measurement systems. Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, OH 44139; Tel: 800-552-1115; Fax: 440-248-6168; www.keithley.com

Keithley Instruments, Inc.

For More Information Circle No. 607

NEW DATA ACQUISITION CATALOG

Keithley Instruments' 1998 Data Acquisition Catalog presents PC-based and standalone measurement solutions for benchtop, distributed, and portable applications in the lab or factory. These include real-time DA/controller boards, DA and communications PCMCIA cards, miniaturized instruments with built-in signal conditioning, motor controller boards, benchtop and board-level DMMs and VMMs, and more. Keithley Instruments, Inc., 28775 Aurora Road, Cleveland, OH 44139; Tel: 800-552-1115; Fax: 440-248-6168; www.keithley.com

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For More Information Circle No. 608

LATEST BOOK TEACHES NONLINEAR FEA & MECHANICAL EVENT SIMULATION

Linear and Nonlinear Finite Element Analysis in Engineering Practice explores nonlinear and linear theory. *Finite Element Modeling in Engineering Practice* is the industry standard for linear analysis. CD-ROM has search engine and color graphics. Address: 150 Beta Dr., Pittsburgh, PA 15238.

APD

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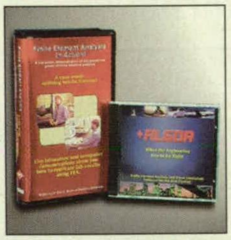

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Finite Element Analysis in Action! is a proven, effective, instructional video and interactive CD-ROM for engineers. Live laboratory and computer demonstrations show how to better use any FEA software. Learn more about the basic physical principles behind FEA, how engineering judgment affects analysis, how tiny flaws affect material strength, boundary conditions, and more. APD, 150 Beta Dr., Pittsburgh, PA 15238; Tel: 1-800-48-ALGOR; Fax: 412-967-2781; apd@algor.com; www.algor.com

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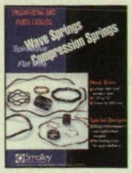
LITERATURE SPOTLIGHT



WAVE/COMPRESSION SPRING CATALOG

Just updated, Catalog #WS-93A contains hundreds of NEW stock sizes of wave/compression springs available from stock, including spring design formulas, materials guide, and typical applications. This 40-page engineering/parts manual describes Smalley's exclusive edgewinding manufacturing process. SPECIAL SPRINGS ARE EASY TOO! Smalley springs, available from 3/8" to 84" in diameter, are produced by circle-coiling flat wire to exact specifications involving no dies or special tooling charges. Smalley Steel Ring Co., 385 Gilman Ave., Wheeling, IL 60090; Tel: 847-537-7600; Fax: 847-537-7698; http://www.ringspring.com.

Smalley Steel Ring Co.

For More Information Circle No. 612

VIBRATION ISOLATION & IMPACT ABSORPTION

New, full-color brochure describes the dynamic properties of Sorbothane, the unique vibration isolation and impact absorption material. New test data details the damping properties of Sorbothane compared to other elastomers. Sorbothane is a patented visco-elastic polymer. Includes information on Sorbothane's new line of advanced vibration isolation/shock absorption products, as well as applications engineering, manufacturing capabilities, and the many applications for Sorbothane. Sorbothane, Inc.; Tel: 330-678-9444; Fax: 330-678-1303; e-mail: webmaster@www.sorbothane.com; http://www.sorbothane.com

Sorbothane, Inc.

For More Information Circle No. 613

VACUUM PUMP VIBRATION ISOLATORS

The NEC vibration isolators effectively remove turbo-molecular and cryo-pump vibrations. Two models are available in elastomer and air-isolated versions. They are UHV compatible, have short insertion lengths, and high conductance. A wide variety of flanges are available. National Electrostatics Corp., 7540 Graber Rd., Box 620310, Middleton, WI 53562-0310; Tel: 608-831-7600; Fax: 608-256-4103; http://www.pelletron.com

National Electrostatics Corp.

For More Information Circle No. 614

ELECTRONIC HARDWARE

Globe Electronic Hardware, Inc. introduces its latest 260-page catalog, which provides complete engineering dimensions and specifications for our entire line of precision electronic hardware. Products include: Standoffs, Spacers, Captive Panel Screws, Retainers, Handles, Ferrules, and other quality components in both American and METRIC standards. Globe Electronic Hardware, Inc.; Tel: 800-221-1505; Fax: 718-457-7493; www.globelectronics.com

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For More Information Circle No. 615

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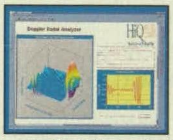
Quatech's new 1998 product handbook details our extensive line of quality communication, data acquisition, and signal conditioning products for PCMCIA, ISA, and PCI. New for 1998 are 2- and 4-port RS-232 PCI serial adapters and the SignalPro Series of board level signal conditioning modules. Product overviews, photos, and complete technical specifications are provided. For your free copy call 1-800-553-1170; e-mail: sales@quatech.com; or visit our website: http://www.quatech.com

Quatech, Inc.

For More Information Circle No. 616



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National Instruments

For More Information Circle No. 617

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The AstroDAQ paperless data acquisition system for acquiring, conditioning, analyzing, and networking data includes a wide variety of signal conditioners with A/Ds and sampling circuitry, plus a high-capacity hard drive. Signal conditioner modules include built-in DSP-based circuitry for virtually unlimited programmable filtering. An AstroDAQ can be configured with six modules to provide 30 waveform channels; up to 10 AstroDAQs (300 channels) can be networked and controlled by a single PC. Astro-Med, Inc., Astro-Med Industrial Park, West Warwick, RI 02893; Tel: 401-828-4000; Fax: 401-822-2430; astro-med@astro-med.com

Astro-Med, Inc.

For More Information Circle No. 618

1998 PCMCIA PRODUCTS CATALOG

The new PCMCIA-PC CARD standard has been incorporated into applications such as datalogging, agriculture, digital film, and wireless communications. Envoy Data has just released its new catalog for these new applications, plus many other products like: memory; I/O (serial, parallel, SCSI, A/D) cards; PC card drives for ISA, IDE, SCSI; and industrial cards and drives, multimedia, industrial, and engineering tools for PCMCIA applications. Envoy Data Corporation, 6 E. Palo Verde, #3, Gilbert, AZ 85296; Tel: 602-892-0954; Fax: 602-892-0029; e-mail: info@envoydata.com; www.envoydata.com

Envoy Data Corporation

For More Information Circle No. 619

PRECISION POSITIONING REFERENCE GUIDE

From modular units to turnkey positioning systems, the best solutions for controlled motion can be found in this 336-page catalog of Parker Precision Positioning Products. With a full line of linear and rotary tables, featuring a wide assortment of bearing and drive technologies, this catalog is the ideal reference guide for controlled motion and positioning. Parker Hannifin, Daedal Div.; Tel: 800-245-6903; www.daedalpositioning.com

Parker Hannifin, Daedal Div.

For More Information Circle No. 620

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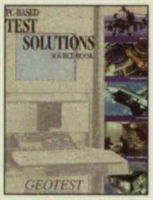
W.M. Berg, Inc.

For More Information Circle No. 621



FREE TEST SOLUTION CATALOG

New, free, 64-page 1998 PC-Based Test Solution Source Book from Geotest (Marvin Test Systems, Inc.). Features over 100 PC-based products for ATE, data acquisition, and test & measurement applications. New products featured include: GT50-DIO dynamic digital I/O, NT5000 ROM Emulator, GT40-RFS 200MHz Multiplexer, GT614-SM high density switch matrix, GTXI instrumentation chassis, and more. Call for your free copy. Geotest/Marvin Test Systems, Inc.; Tel: 888-TEST-BY-PC (837-8297) or 714-263-2222; www.geotestinc.com

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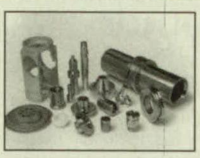
For More Information Circle No. 622



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For More Information Circle No. 623

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SYSTRAN Corp.

For More Information Circle No. 624

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Strainsert

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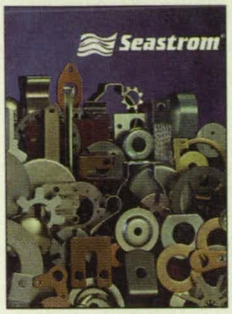

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For More Information Circle No. 627

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For More Information Circle No. 628

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Barnant Company

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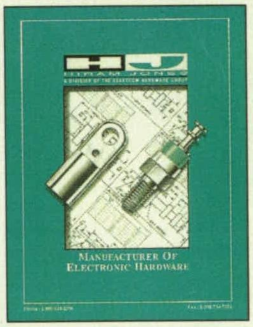

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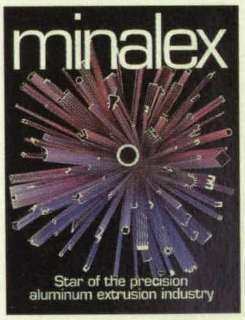

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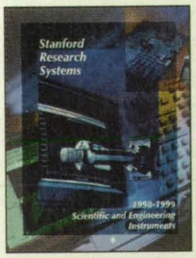

STANFORD RESEARCH SYSTEMS 1998-99 CATALOG

The new 1998-1999 Scientific and Engineering Instruments catalog from Stanford Research Systems contains product specifications, prices, and application notes on our full line of instruments. This 200-page catalog also has new product information as well as a current listing of our international representatives. Stanford Research Systems, 1290 D Reamwood Ave., Sunnyvale, CA 94089; Tel: 408-744-9040; Fax: 408-744-9049; e-mail: info@srsys.com; www.srsys.com/srsys/

Stanford Research Systems

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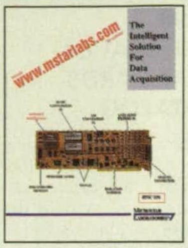

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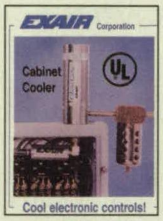

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OMEGA Engineering

For More Information Circle No. 641

NEW 1998 DATA ACQUISITION BOARDS SUPPLEMENT CATALOG

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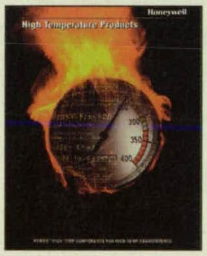
DATEL SYSTEMS

For More Information Circle No. 642



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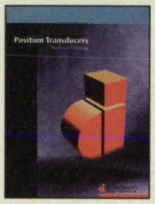

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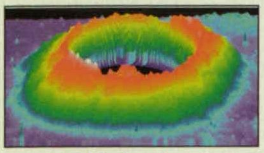

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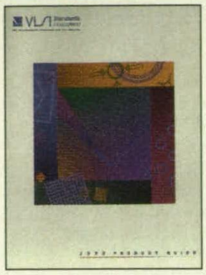

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VLSI Standards

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For More Information Circle No. 650

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Love Controls Div., Dwyer Instru.

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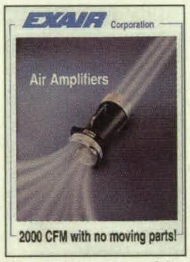

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Danfoss Electronic Drives

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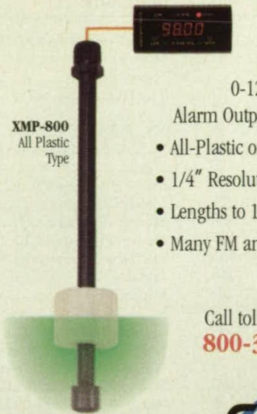

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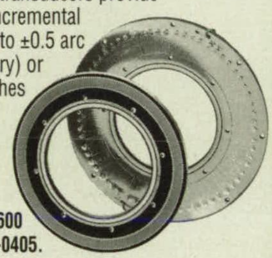

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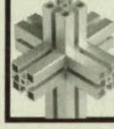

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